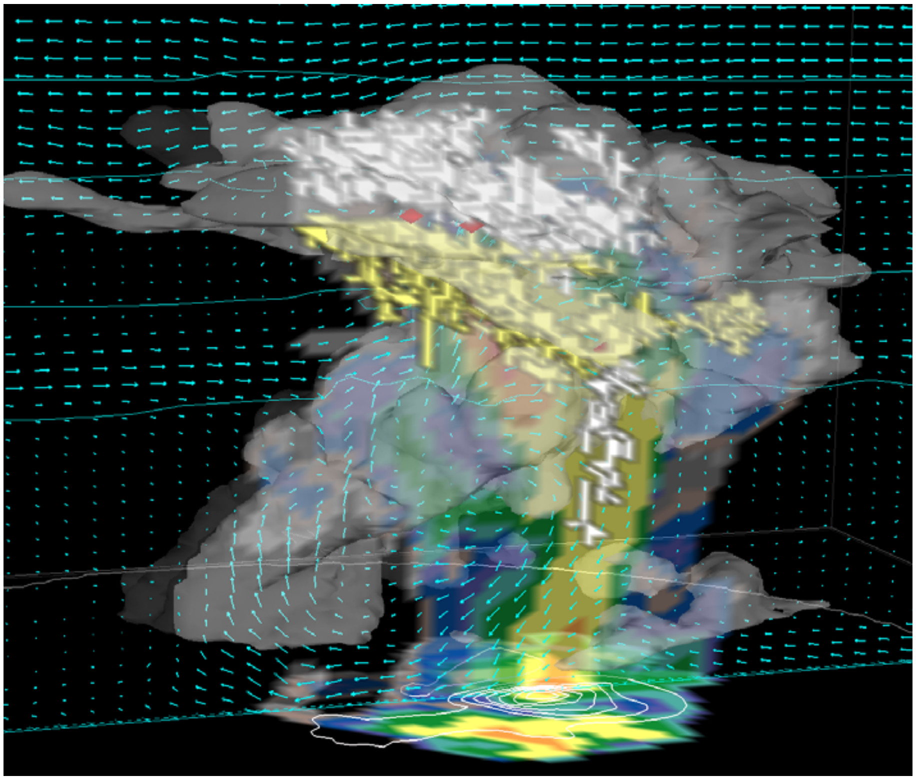


Cooperative Institute for Mesoscale Meteorological Studies

Annual Report

Prepared for the
National Oceanic and Atmospheric Administration
Office of Oceanic and Atmospheric Research
NOAA NA17RJ1227
Fiscal Year – 2005

Cover figure – *Improved simulation of a small Florida thunderstorm with predicted number concentration of hydrometeors. Three lightning flashes are depicted. Negatively-charged lightning channels (white) indicate the upper main positive and lower positive ambient charge regions. Positively-charged lightning channels (yellow) indicate the main ambient negative charge region. The light gray surface denotes the simulated cloud boundary. The vertical electric field value at the surface is shown by white contour lines (intervals of 1 kV/m). Simulated reflectivity is shown at the surface and a vertical plane through the storm along with wind vectors. Wind vectors are spaced at 500m horizontally and 250m vertically. (The model resolution is 250m by 125m.) Cloud droplets form in the updraft on the left (west) side, and precipitation helps drive the downdraft. Cloud top height is about 9.8 km AGL. Isotherms are indicated by light blue contours (in plane of the vectors, from 0 to -40C in 10 degree increments). For more on this project, see* ***Investigation of Synoptic and Mesoscale Meteorological Processes Associated with Hazardous Weather – Thunderstorm Electrification Modeling****, by Ted Mansell, Conrad Ziegler, Jerry Straka, Don MacGorman, and Kristin Kuhlman, under research theme* ***Basic Convective and Mesoscale Research****.*

Table of Contents

COOPERATIVE INSTITUTE FOR MESOSCALE METEOROLOGICAL STUDIES
THE UNIVERSITY OF OKLAHOMA

Annual Report of Research Progress under Cooperative Agreement NA17RJ1227
During Fiscal Year 2005

Peter J. Lamb, Director
Randy A. Peppler, Associate Director

INTRODUCTION

General Description of CIMMS and its Core Activities

The Cooperative Institute for Mesoscale Meteorological Studies (CIMMS) was established in 1978 as a cooperative program between the National Oceanic and Atmospheric Administration (NOAA) and the University of Oklahoma (OU). CIMMS provides a mechanism to link the scientific and technical resources of OU and NOAA to create a center of research excellence in mesoscale meteorology, regional climate studies, and related subject areas. CIMMS-supported scientists and students conduct research in mesoscale dynamics, radar research, development, and analysis, atmospheric electricity, severe storms, cloud microphysics, and boundary layer studies, with increasing emphasis in recent years on the climatic effects of/controls on mesoscale processes, the socioeconomic impact of such phenomena, and climate change monitoring and detection. Outreach activities are also performed in a number of ways described later in this report.

CIMMS promotes cooperation and collaboration on problems of mutual interest among OU research scientists and students and the NOAA Office of Oceanic and Atmospheric Research (OAR) National Severe Storms Laboratory (NSSL), National Weather Service (NWS) Radar Operations Center (ROC) for the WSR-88D (NEXRAD) Program, NWS NCEP (National Centers for Environmental Prediction) Storm Prediction Center (SPC), NWS Warning Decision Training Branch (WDTB), and a NWS Forecast Office, all located in Norman, Oklahoma. CIMMS also fosters collaboration with the NWS National Environmental Satellite, Data, and Information Service (NESDIS) National Climatic Data Center (NCDC) in Asheville, NC, and with the NWS Southern Region Headquarters (SRH) in Fort Worth, TX.

CIMMS research contributes to the NOAA mission through improvement of the observation, analysis, understanding, and prediction of weather elements and systems and climate anomalies ranging in size from cloud nuclei to multi-state areas. Advances in observational and analytical techniques lead to improved understanding of the evolution and structure of these phenomena. Understanding provides the foundation for more accurate prediction of hazardous weather and anomalous regional climate. Better prediction contributes to improved social and economic welfare. Because small-, meso-, and regional-scale phenomena are also important causes and manifestations of climate, CIMMS research is contributing to improved understanding of the global climate system and regional climate variability and change. CIMMS promotes research collaboration between scientists at OU and NOAA by providing a center where government and academic scientists may work together to learn about and apply their knowledge of mesoscale weather and regional-scale climate processes.

CIMMS is part of the National Weather Center, a unique confederation of federal, state, and OU organizations that work together in partnership to improve understanding of the Earth's atmosphere. Recognized for its collective expertise in severe weather, many of the research and development activities of the Center have served society by improving weather observing and forecasting, and thus have contributed to reductions in loss of life and property. Many entities of the National Weather Center played a key role in the decade-long, $2 billion dollar modernization and restructuring of the National

Weather Service. National Weather Center organizations employ nearly 650 men and women and provide more than $45 million annually to the Oklahoma economy.

In addition to CIMMS, National Weather Center organizations include:

- NOAA OAR National Severe Storms Laboratory
- NOAA NWS Warning Decision Training Branch
- NOAA NWS NCEP Storm Prediction Center
- NOAA NWS Radar Operations Center
- NOAA NWS Weather Forecast Office - Norman, OK
- Oklahoma Climatological Survey
- OU College of Geosciences
- OU School of Meteorology
- OU Department of Geography
- OU Center for Analysis and Prediction of Storms (CAPS)
- OU Center for Spatial Analysis
- OU Environmental Verification and Analysis Center
- OU International Center for Natural Hazards and Disaster Research
- OU Sasaki Institute
- OU Supercomputing Center for Education and Research

This report describes the research progress made by CIMMS scientists at OU and those assigned to our collaborating NOAA units during OU fiscal year 2005 (1 July 2004 through 30 June 2005), and as such represents the fourth of five annual reports to be written for the present cooperative agreement (NA17RJ1227). CIMMS concentrates its research efforts and resources on the following principal themes: (1) basic convective and mesoscale research, (2) forecast improvements, (3) climatic effects of/controls on mesoscale processes, (4) socioeconomic impacts of mesoscale weather systems and regional-scale climate variations, (5) Doppler weather radar research and development, and (6) climate change monitoring and detection. Activities in Public Affairs and Outreach are also presented, along with information on publications written, awards received, and employee and funding statistics. This report also documents the research and outreach activities performed by CIMMS scientists who are funded by other agencies – these agencies are identified.

Management of CIMMS, including Mission and Vision Statements, and Organizational Structure

CIMMS is defined organizationally by a Memorandum of Understanding between NOAA and OU, signed last in 1995. It is governed, as specified in the MOU, by an Advisory Board, Council, and Assembly of Fellows. A review of CIMMS was conducted by the NOAA Science Advisory Board in October 2003. One result of this review was the development of a strategic plan for 2006-09 (an executive summary is included in Appendix D).

The Advisory Board, chosen with the advice and consent of the Fellows, OAR, NWS, and the university, provides advice on new and existing scientific program areas, and serves in a review and advisory capacity on budgetary and administrative matters. The Board may modify or expand its composition as appropriate to changing needs. Members of the Advisory Board should be well qualified to evaluate the program of the CIMMS, to judge performance, and to make appropriate suggestions for change. Members At Large may be from either U.S. or foreign institutions; their appointments are usually for three years, and are renewable. If requested, the CIMMS Council will submit a slate of nominations for new members or additions to the Advisory Board. The complete Board will meet regularly to review and comment upon CIMMS programs, administration, and budget. Other meetings of the complete Board may be called by the Chair, by the Provost, by the Directors of OAR or NWS, or by a majority of the members. With the NOAA Science Advisory Board taking over the responsibility of reviewing CIMMS, the CIMMS Advisory Board no longer meets.

The Council meets regularly to provide advice and recommendations to the Director of CIMMS regarding appointments, procedures, and policies; to review and adopt bylaws; and to periodically review the accomplishments and progress of the technical and scientific programs and projects of the CIMMS. The Council's advice should not be viewed as binding on the Director relative to any recommendations that might be carried forward to the Advisory Board.

The Assembly of Fellows is composed of a cross-section of local and national scientists who have expertise relevant to the research themes of CIMMS and are actively involved in the programs and projects of CIMMS. Appointment to the Assembly, by the CIMMS Council, is normally for a two year term, and reappointment is possible. Appointments may be made for a shorter period of time or on a part-time basis with the concurrence of the appointee and the CIMMS Council. The Assembly will review and suggest modifications of bylaws, participate in reviews of CIMMS activities, and elect two of their number to serve on the Council. The Assembly's advice should not be viewed as binding on the Director relative to any recommendations that might be carried forward to the Advisory Board. Fellows are appointed by the Council.

The Mission and Vision Statements of CIMMS are as follows:

Mission *– To promote collaborative research between NOAA and OU scientists on problems of mutual interest to improve basic understanding of mesoscale meteorological phenomena, weather radar, and regional climate to help produce better forecasts and warnings that save lives and property*

Vision *– A center of research leadership and excellence in mesoscale meteorology, weather radar, regional climate, and forecast and warning improvement, fostering strong government/university collaborations*

The organizational structure of CIMMS includes a Director (Peter Lamb), Associate Director (Randy Peppler), Assistant Director for NOAA Relations (Randy Peppler), Financial and Personnel Administrator (Tracy Reinke), Administrative Assistant (Luwanda Byrd), and two Staff Assistants (Judy Henry and Debbie Mattax). Scientists, students, and post-docs are housed at the University of Oklahoma’s Sarkeys Energy Center, in addition to at NSSL, SPC, ROC, WDTB, and SRH. Peppler and Reinke hold dual offices in both the Energy Center and at NSSL.

Executive Summary of Important Activities and Results during FY2005

Basic Convective and Mesoscale Research

The primary goals of this original CIMMS thematic area are to understand cloud and mesoscale dynamics, microphysics and the precipitation process and their relationships to large and small scale forcing, and to develop procedures for assimilation of meteorological data into simulation and prediction models of these processes. The work done here represents a fundamental building block for eventual applied techniques.

During the past year, research was conducted on:

- Severe weather warning applications and development
- Ensemble Kalman filter assimilation of multisensor observations from convection for storm-scale analysis
- Thunderstorm Electrification and Lightning Experiment (TELEX)
- Thunderstorm electrification modeling
- Cold fronts
- Mammatus cloud observations, mechanisms, and modeling
- Convective system propagation in models that use parameterized convection

- Measurement and analysis of the preconvective boundary layer and convection initiation during IHOP
- Dynamics of hurricanes at landfall
- Role of storm dynamics on cloud electrification
- Concentrating vorticity near the ground – investigation of supercell rear-flank precipitation, vorticity generation, and transport processes
- Numerical simulations of derecho-producing convective systems
- Study of the genesis, evolution, structure, and dynamic climatology of tornadoes and their environments - radar-based climatology of tornado structure and dynamics
- Effects of multi-dimensional radiative transfer on cloud system evolution
- Turbulence structure of cold season continental stratocumulus
- Statistical formulations of cloud parameters over the U.S. Southern Great Plains
- Parameterization of cloud microphysics and radiation
- Mesoscale dynamics
- Doppler radar data quality control, analyses and assimilation
- Numerical modeling study of the time-dependent behavior of convection
- Hodograph-based supercell storm motion estimates
- Vertical vortices in the convective boundary layer
- Martian dust devils
- Idealized convection in shear
- Evaluations of microphysical parameterizations

Forecast Improvements

The primary goal of this original thematic area is to accelerate the transfer of research knowledge and skills between the academic and NOAA operational mesoscale meteorological communities to both improve the design and utilization of mesoscale weather observing systems and improve mesoscale weather prediction and warning.

During the past year, research was conducted on:

- Advanced Warning Operations Course (AWOC)
- AWIPS and WSR-88D improvements
- Weather Event Simulator
- Distance Learning Operations Course (DLOC)
- Winter Weather Track, Advanced Warning Operations Course
- Training on NOAA Management and Business Practices
- WDTB Research and Training Lab
- WDTB Training and Research Toolkit and Real-Time System
- National Basin Repository and Flash Flood tools for FFMP in AWIPS
- Enhanced hydrometeor classification algorithm for dual-polarimetric radar
- Polarimetric radar applications
- WDSS-II ITR: A real time mining of integrated weather data
- SPC/NSSL Hazardous Weather Testbed Spring Program
- Forecast verification
- Methods to provide improved forecasts of near surface conditions through use of ensemble forecasts
- Refinement and experimental application of the Kain-Fritsch convective parameterization
- Comparison of triangulation and pentagon methods for estimating divergence
- Regional-scale sounding network in support of the North American Monsoon Experiment (NAME)
- Science and technology infusion
- Advancing science to improve knowledge of mesoscale hazardous weather
- Communicating weather information effectively using the Internet

- Evaluation of synoptic-scale controls on tornado outbreaks
- A European climatology of severe weather related parameters
- Tri-State tornado reanalysis
- Parameterizing cloud-aerosol interactions in regional forecast models
- Advanced weather data visualization
- Development of a tool to aid in forecasting the evolution of late-morning MCS activity
- Land-atmosphere memory quantified using observations from the Oklahoma Mesonet and the NOAH land surface model
- Contribution to the WRF model development by CAPS

Climatic Effects of/Controls on Mesoscale Processes

The primary goal of this thematic area is to extend and apply the understanding of mesoscale processes to the problem of climate maintenance and change. This theme also includes investigation of the influence of the large-scale climatic environment on the mesoscale systems that produce growing season rainfall in regions such as central North America and Sub-Saharan Africa.

During the past year, research was conducted on:

- Evidence of tropospheric biennial oscillation and influence of the Indian Ocean over the horn of Africa
- Influence of intertropical front on rainfall variability in West Africa Sahelian countries
- Pan American Climate Studies Sounding Network (PACS-SONET)
- Severe weather climatology via reanalysis soundings – weather and climate assessment Initiative

Socioeconomic Impacts of Mesoscale Weather Systems and Regional Scale Climate Variations

The primary goal of this thematic area is to estimate the socioeconomic impacts and values of mesoscale weather systems and regional-scale climate variations in central and eastern North America and across the world, to facilitate the mitigation (enhancement) of the adverse (beneficial) impacts. A continuing component of this work makes extensive use of climate scenarios and economic models, and is performed in collaboration with agricultural economists and social scientists. It is also complemented by a research thrust that is addressing a spectrum of weather- and climate-related disaster issues.

During the past year, research was conducted on:

- Energy indices
- Tornado warning lead time and tornado casualties
- Multiscale evolution and predictability of a warm season climate anomaly in the U.S. Southern Great Plains
- Extreme temperature events in North America east of the Rocky Mountains: A summer climate analysis

Doppler Weather Radar Research and Development

The primary goal of this thematic area is to accelerate the transfer of knowledge between the meteorological and engineering communities (in academia, and government and private laboratories) to improve the design, usability, and supportability of the NEXRAD WSR-88D Doppler weather radar. Continual enhancements are needed to the system for improving the quality, format, accuracy, resolution, and update rate of the base data, and to keep pace with evolving hardware and software technologies. This work introduces, examines, and analyzes present and future technologies, including phased-array technology, with the goal of meeting the unfulfilled radar needs. This theme also includes a fertile research area for development and improvement of radar algorithms used for forecasting and warning.

During the past year, research was conducted on:

- Improved Quantitative Precipitation Estimation (QPE)
- National Mosaic and Multi-Sensor QPE (NMQ) enhancement and improvement
- VCPExplorer
- Polarimetric rainfall estimation
- Polarimetric classification of meteorological and non-meteorological scatterers
- Radar polarimetry at shorter wavelengths
- Dual-polarization algorithm development and testing
- Polarimetric signal processing
- Mitigation of range and velocity ambiguities
- Improvement of spectral moment and polarimetric variable estimates using decorrelating transformations on ovversampled range data
- Super Resolution Radar Data
- Radar data quality for the Korean Meteorological Administration
- National Weather Radar Testbed – Phased Array Radar
- Phased Array Radar beam multiplexing
- Phased Array Radar scheduler
- Phased Array Radar IQ data browser
- Phased Array Radar scalable signal processing
- Phased Array Radar simultaneous archiving of IQ and moments data
- WSR-88D algorithm evaluation and improvement, and data quality
- NEXRAD technology transfer
- Emergency mobile radar
- Improving tornado detection with WSR-88D data using spectral analysis
- Enhancement of radar retrievals by the use of higher moments of drop spectrum
- Continued support for the Internet-based delivery of WSR-88D Level II data in near real time (IRaDS)

Climate Change Monitoring and Detection

The goal of this research theme is to study climate change monitoring and detection in general, and specifically the homogeneity or lack thereof of the historical station records in the U.S. and to use this information to help address the climate change questions.

During the past year, research was conducted on:

- Detection and attribution of climate change using climate indices for the United States
- Development and application of dynamic normals for investigation of climate variation and change
- Integration of weather system variability to multidecadal regional climate change: West African Soudano-Sahel zone (1951-98)
- Systems integration and prototype COOP operations management
- Prototype a modernization data ingest and quality assurance system for a National Surface Mesonetwork
- GIS-based selection of potential National Weather Service COOP sites: A pilot study in Maine, New Hampshire, and Vermont
- Field surveys for COOP and LETS locations in New England
- Development of a comprehensive GIS model to prototype a new National Weather Service COOP Network
- Climatology of drizzle in the United States and Canada
- ARM Program Data Quality Office
- ARM Program Southern Great Plains Site Scientist Team

- ARM Program Soil Water and Temperature System instrument mentorship
- Project support for the assimilation, analysis and dissemination of Pacific rainfall data – PACRAIN

Public Affairs and Outreach

During the past year, public affairs and outreach activities included:

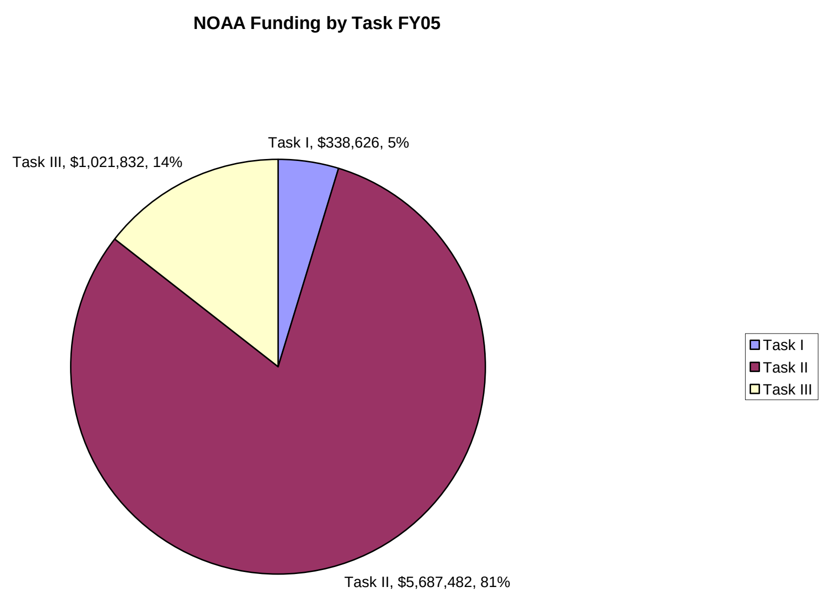
- National Weather Center Research Experiences for Undergraduates Program
- ARM Program Outreach
- Outreach Activities performed by CIMMS Staff at NSSL, WDTB, SRH and ROC

Awards

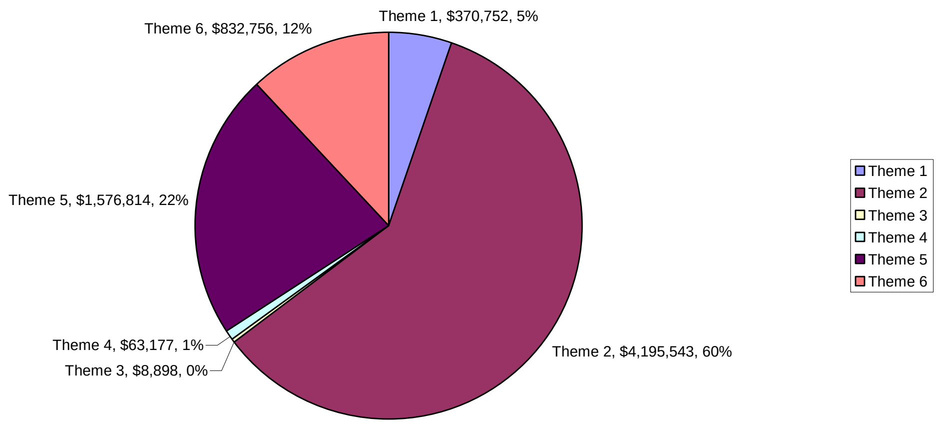
The following awards were bestowed or nominations made:

- 2005 Sergey Soloviev Medal – *Charles Doswell III – CIMMS Research Scientist*
- 2005 Certificate of Appreciation from NWS Southern Region Headquarters – *Leon Minton, CIMMS Scientist at SRH*
- NOAA OAR Outstanding Scientific Paper Award – *Igor Ivic, Sebastian Torres, and Dusan Zrnic, CIMMS Scientists at NSSL*
- 2005 American Meteorological Society Special Award – 85th Annual Meeting – *Oklahoma Mesonet*
- Nominated by NWS for a Department of Commerce Gold Medal for their development of the Advanced Warning Operations Course (AWOC) – *Warning Decision Training Branch*
- 2005 Yoshi Sasaki Award for Best M.S. Student Publication – *Zewdu Segele, CIMMS Graduate Student*

Distribution of NOAA Funding by CIMMS Task and Theme



NOAA Funding by Theme



CIMMS Council and Fellows Membership and Meeting Dates

As described above, CIMMS is governed by the CIMMS Council and the Assembly of Fellows. During the Fiscal Year, a CIMMS Council meeting was held November 22, 2004. Council meetings immediately subsequent and prior to the 2005 Fiscal Year were held on April 2, 2004 and August 11, 2005, respectively.

CIMMS Council membership includes:

- Dr. Peter J. Lamb (Chair), George Lynn Cross Research Professor of Meteorology, OU, and Director, CIMMS
- Dr. Kenneth C. Crawford, Regents' Professor of Meteorology, OU, and Director, OCS (Provost designated)
- Dr. Jerry Crain, Professor and Director, School of Electrical and Computer Engineering (Provost designated)
- Dr. Baxter E. Vieux, Presidential Professor of Civil Engineering & Environmental Science, OU (Provost designated)
- Dr. David J. Stensrud, Research Meteorologist and Team Leader, Models and Assimilation Team, NSSL, and Affiliate Professor, School of Meteorology, OU (OAR designated)
- Mr. Kevin Kelleher, Deputy Director, NSSL (OAR designated)
- Dr. Russ Schneider, Chief, Science Support Branch, SPC (NWS designated)
- Mr. Mark Fresch, Radar Operations Center Applications Branch (NWS Designated)
- Dr. Michael L. Biggerstaff, Associate Professor of Meteorology, OU (Elected from CIMMS Assembly of Fellows)
- Mr. Doug Forsyth, Chief, Radar Research & Development Division, NSSL (Elected from CIMMS Assembly of Fellows)
- Dr. Frederick H. Carr, Director, OU School of Meteorology, and McCasland Chair Professor of Meteorology, and Associate Director, CAPS (ex-officio member)
- Dr. James F. Kimpel, Director, NSSL, and Emeritus and Affiliate Professor of Meteorology, OU (ex-officio member)
- Dr. Joseph T. Schaefer, Director, SPC, and Affiliate Professor of Meteorology (ex-officio member)
- Mr. Ed Mahoney , Director, WDTB (ex-officio member)
- Mr. Richard Vogt, Director, ROC (ex-officio member)
- Mr. Mike Foster, Meteorologist-in-Charge, Norman WFO (ex-officio member)
- Mr. William Proenza, Director, NWS Southern Region Headquarters (ex officio member)
- Dr. Tom Karl, Director, NCDC (ex officio member)

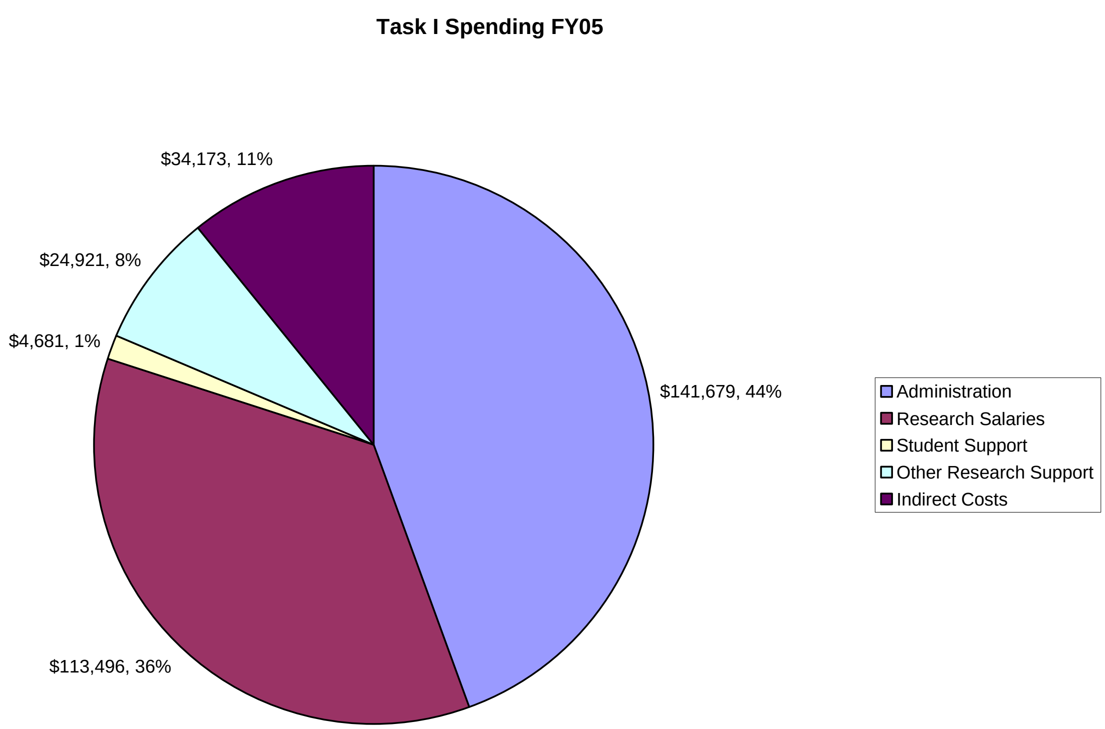
CIMMS Fellows membership includes:

- Dr. Jeffrey B. Basara, Director of Research, OCS and Affiliate Assistant Professor of Meteorology, OU

- Dr. William H. Beasley, Professor of Meteorology, OU
- Mr. James D. Belville, Emeritus Director, ROC
- Dr. Michael I. Biggerstaff, Associate Professor of Meteorology, OU
- Dr. Howard B. Bluestein, Presidential Professor of Meteorology, OU
- Dr. Harold E. Brooks, Research Meteorologist and Team Leader, Mesoscale Applications Group, NSSL
- Dr. Frederick H. Carr, McCasland Chair Professor of Meteorology and Director, School of Meteorology, OU, and Associate Director, CAPS
- Dr. Gerald E. Crain, Director, School of Electrical and Computer Engineering, OU
- Dr. Kenneth C. Crawford, Regents' Professor of Meteorology, OU, and Director, OCS, OU
- Dr. Timothy D. Crum, Chief, Operations Branch, ROC
- Dr. Charles A. Doswell, III, retired, NSSL
- Dr. Michael W. Douglas, Research Meteorologist, Mesoscale Applications Group and Models and Assimilation Team, NSSL
- Dr. Richard J. Doviak, Senior Engineer, Doppler Radar and Remote Sensing Research Group, NSSL, and Affiliate Professor of Meteorology and of Electrical and Computer Engineering, OU
- Dr. Kelvin K. Droegemeier, Regents' Professor of Meteorology, OU, Director, CAPS, Director, Sasaki Institute, and OU Assistant Vice President for Research
- Dr. Claude E. Duchon, Emeritus Professor of Meteorology, OU
- Dr. Imke Durre, Scientist, NCDC
- Dr. David R. Easterling, Scientist, NCDC
- Mr. Douglas E. Forsyth, Chief, Radar Research & Development Division, NSSL
- Dr. Carl E. Hane, Research Meteorologist, Convective Weather Research Group, NSSL, and Affiliate Professor of Meteorology, OU
- Dr. David P. Jorgensen, Chief, Warning Research & Development Division, NSSL
- Dr. Eugenia Kalnay, Professor of Meteorology, University of Maryland
- Dr. David Karoly, Williams Chair Professor of Meteorology, OU
- Dr. Petra Kastner-Klein, Assistant Professor of Meteorology, OU
- Mr. Kevin E. Kelleher, Deputy Director, NSSL
- Dr. James F. Kimpel, Director, NSSL, and Emeritus Professor of Meteorology, OU
- Mr. Paul Kirkwood, Scientist, NOAA NWS Southern Region Headquarters
- Dr. S. Lakshmivarahan, George Lynn Cross Research Professor of Computer Science, OU
- Dr. John Latham, Senior Research Associate, National Center for Atmospheric Research (NCAR)
- Mr. Leslie R. Lemon, Radar, Severe Storms, and Research Meteorologist, Basic Commerce and Industries, Inc., Moorestown, NJ
- Dr. Lance M. Leslie, Robert E. Lowry Chair and Professor of Meteorology, OU
- Mr. Jason Levit, Techniques Development Meteorologist, SPC
- Dr. John M. Lewis, Research Meteorologist, Models and Assimilation Team, NSSL, and Affiliate Professor of Meteorology, OU
- Dr. Douglas K. Lilly, Senior Research Meteorologist, NSSL, and Robert E. Lowry Chair Emeritus and George Lynn Cross Research Professor of Meteorology Emeritus, OU
- Dr. Donald R. MacGorman, Research Physicist, Convective Weather Research Group, NSSL, CIMMS Resident Fellow, and Affiliate Professor of Meteorology and of Physics and Astronomy, OU
- Dr. Renee McPherson, Acting Director, Oklahoma Climatological Survey, OU
- Mr. Ed Mahoney, Chief, WDTB
- Dr. Catherine Mavriplis, Department of Mathematics, OU
- Dr. James W. Mjelde, Professor of Agricultural Economics, Texas A&M University
- Mr. David L. Montroy, Meteorologist, WeatherNews Americas, Inc., (WNI)
- Dr. Mark L. Morrissey, Professor of Meteorology, OU
- Dr. Robert D. Palmer, Professor of Meteorology, OU
- Dr. Ramkumar Parthasarathy, Assistant Professor of Aerospace and Mechanical Engineering, OU
- Dr. Thomas C. Peterson, Scientist, NCDC
- Mr. John R. Reed, Chief, Open System Team, ROC
- Dr. Michael B. Richman, Associate Professor of Meteorology, OU
- Dr. W. David Rust, Chief, Forecast Research and Development Division, and Team Leader, Field Observing Facilities and Services, NSSL, and Affiliate Professor of Meteorology and of Physics and Astronomy, OU
- Dr. Joseph T. Schaefer, Director, SPC, and Affiliate Professor of Meteorology, OU
- Dr. Russell Schneider, Chief, Science Support Branch, SPC

- Dr. Alan M. Shapiro, Associate Professor of Meteorology, OU
- Mr. Dale Sirmans, Senior Engineer, Open Systems Radar Data Acquisition, ROC
- Dr. John T. Snow, Dean, College of Geosciences, OU, and Professor of Meteorology, OU
- Dr. David J. Stensrud, Research Meteorologist and Team Leader - Models and Assimilation Team, NSSL, and Affiliate Professor of Meteorology, OU
- Dr. Jerry M. Straka, Associate Professor of Meteorology, OU
- Dr. Daniel S. Sutter, Associate Professor of Economics, OU
- Dr. Aondover A. Tarhule, Assistant Professor of Geography, OU
- Dr. Baxter E. Vieux, Presidential Professor of Civil Engineering & Environmental Science, OU
- Mr. Richard Vogt, Director, ROC
- Dr. G. Anderson White, III, Lecturer & Affiliate Professor of Meteorology, Associate Director of the Sasaki Institute, OU
- Dr. Louis J. Wicker, Research Meteorologist, Convective Weather Research Group, NSSL, Affiliate Associate Professor of Meteorology, OU
- Dr. Qin Xu, Research Meteorologist, Models and Assimilation Team, NSSL, and Affiliate Professor of Meteorology, OU
- Dr. Tian-You Yu, Associate Professor, School of Electrical and Computer Engineering, OU
- Dr. May Yuan, Assistant Dean, OU College of Geosciences, Associate Professor of Geography, OU, and Director, Center for Spatial Analysis, OU
- Dr. Conrad Ziegler, Research Meteorologist, Models and Assimilation Team, NSSL
- Dr. Dusan S. Zrnic, Senior Engineer and Group Leader, Doppler Radar and Remote Sensing Research Group, NSSL, and Affiliate Professor of Meteorology and of Electrical and Computer Engineering, OU

General Description of Task I Activities



RESEARCH PERFORMANCE

Basic Convective and Mesoscale Research

Convective Weather Research – ***Severe Weather Warning Applications and Development***
Dowell (primary – CIMMS at NSSL), **Burgess**

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: CIMMS Task II – NSSL Project 1

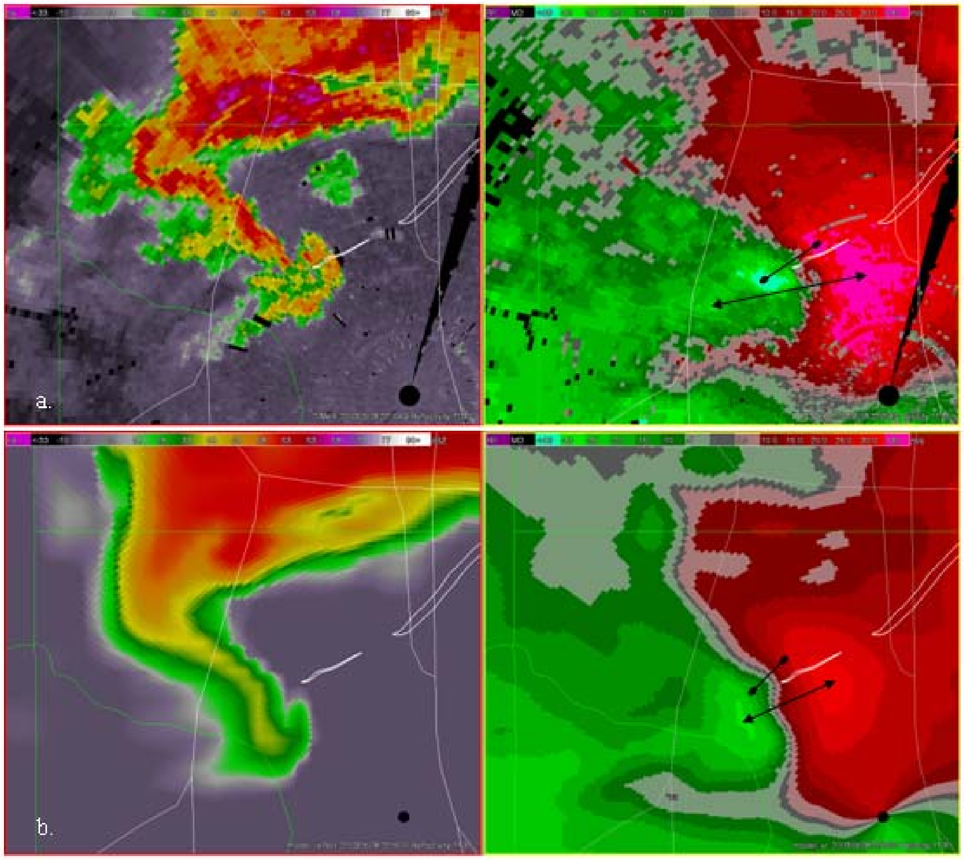
Objectives
Assimilation of radar (and other) observations and numerical modeling of the 8 May 2003 Oklahoma City tornadic supercell; high-resolution storm-scale model experiments of tornadogenesis for the 8 May 2003 Oklahoma City tornado and comparison with radar observations.

Accomplishments
During the reporting year, assimilation, numerical modeling, and comparison studies were done for the entire life cycle of the supercell. During this reporting year, the time interval of the formation of the violent (F4) tornado has been examined more closely. High-resolution assimilation/model output was compared to high-resolution OKC TDWR radar observations. The storm-scale model output was generated by assimilating KOUN single-Doppler reflectivity and radial velocity observations into a cloud model using the ensemble Kalman filter methodology described in Dowell et al. (2004a,b). Model output were compared to observed radar data in several ways, including deriving simulated TDWR observations from model output and comparing with same time and elevation angle TDWR data.

Results indicate that the assimilation/model fields somewhat replicate the TDWR observations (see figure below). TDWR observations reveal the formation of a tornado cyclone and its transition into the tornado. The tornado cyclone is seen in model output, but model velocity magnitudes are less, particularly at low levels, when compared to the observations. Unlike the TDWR data, no model tornado signature is produced at tornadogenesis time. Among possible causes for observation-model differences are the scale of the KOUN assimilation input and the use of ensemble mean output. Individual or groups of ensemble members (50 in all) might better represent the TDWR observations. These and other results suggest attractive paths for further research. However, work to date suggests that there might be some operational value in detecting precursors to tornadogenesis with model fields available in real time from assimilation/model schemes like the one being used here.

This project is ongoing.

Publications
Burgess, D.W., D.C. Dowell, L.J. Wicker, and A. Witt, 2005: Detailed comparison of observed and modeled tornadogenesis. CD-ROM, *32nd Conf. on Radar Meteorology*, Albuquerque, NM, Amer. Meteor. Soc., Paper # 10R.4.
Dowell, D.C, L.J. Wicker, and D.J. Stensrud, 2004a: High resolution analysis of the 8 May 2003 Oklahoma City storm. Part II: EnKF data assimilation and forecast experiments. CD-ROM, *22nd Conf. on Severe Local Storms*, Hyannis, MA, Amer. Meteor. Soc., Paper # 12.5.
Dowell, D.C., F. Zhang, L.J. Wicker, C. Snyder, and N.A. Crook, 2004b: Wind and temperature retrievals in the 17 May 1981 Arcadia, Oklahoma supercell: Ensemble Kalman filter experiments. *Mon. Wea. Rev.*, **132**, 1982-2005.



Reflectivity (left) and radial velocity (right) for (a) TDWR and (b) numerical model at 11.3 deg. elevation angle, 2206 UTC 8 May 2003. Annotated lines on radial velocity mark diameter of mesocyclone (dark arrows) and tornado cyclone (dark circles). Thick white contours are tornado damage areas and dark circle is TDWR location. At the range of the circulations, the height is about 1.25 km AGL.

Convective Weather Research – *Ensemble Kalman Filter Assimilation of Multisensor Observations from Convection for Storm-Scale Analysis*

Dowell, Shapiro, Wicker (primary – NSSL)

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: CIMMS Task II – NSSL Project 1 and NSF

Objectives

Develop techniques for assimilation of Doppler radar observations into cloud-scale models for analysis and forecasts using an Ensemble Kalman Filter approach; understand the issue of model error as it relates to microphysical parameterization error, and how it impacts the data assimilation and how it might be mitigated by other in situ data.

Accomplishments

The ensemble Kalman filter (EnKF; Evensen 1994; Houtekamer and Mitchell 1998) is currently being tested as a method for retrieving the wind, thermodynamic, and microphysical fields in convective storms from radar observations (Snyder and Zhang 2003; Zhang et al. 2004; Dowell et al. 2004; Tong and Xue 2004). Applications for such retrievals include diagnosing storm processes and initializing numerical storm-scale forecast models. The EnKF technique for storm-scale retrieval is being refined according to the results of both Observing System Simulation Experiments (OSSEs) and real-data experiments.

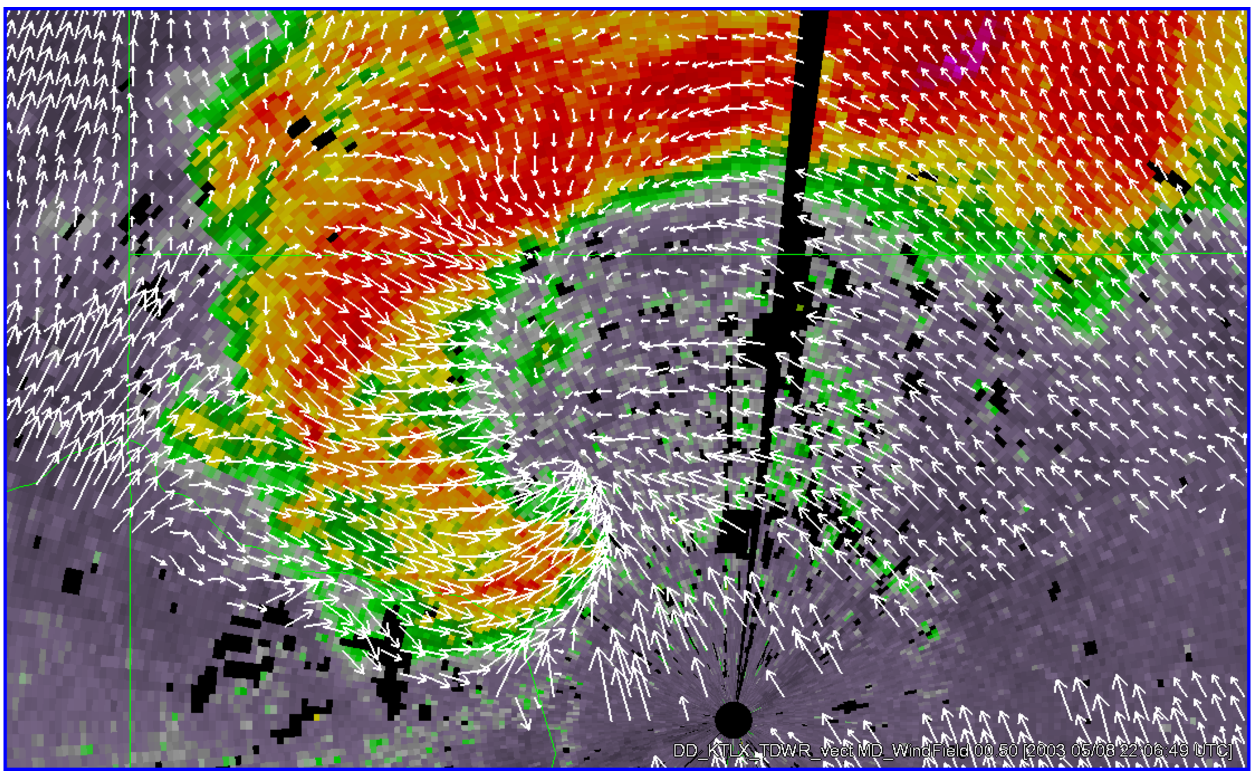
During the past year, considerable progress has been made in several areas. First, detailed analyses of the 8 May 2003 Oklahoma City tornadic storm are being created and compared against high-resolution radar observations from the FAA TDWR radar located very near the storm. These comparisons (see Burgess et al. 2005) indicate that overall the EnKF analysis produces a storm which at the storm and mesocyclone scale is quite realistic compared to the observed storm. However, some errors are noted in the analysis at observed at low levels which seem to indicate an issue with the data from the KOUN radar. We also have developed a software system which can employ 3 different microphysical parameterizations (having increasing complexity) to study the impact of these on the assimilation. Additional work has begun in the last few months to facilitate the incorporation of surface observations into our analysis/forecast system. Observing system experiments are being designed and implemented to study the potential impact of surface observations on the accuracy of the storm-scale analysis.

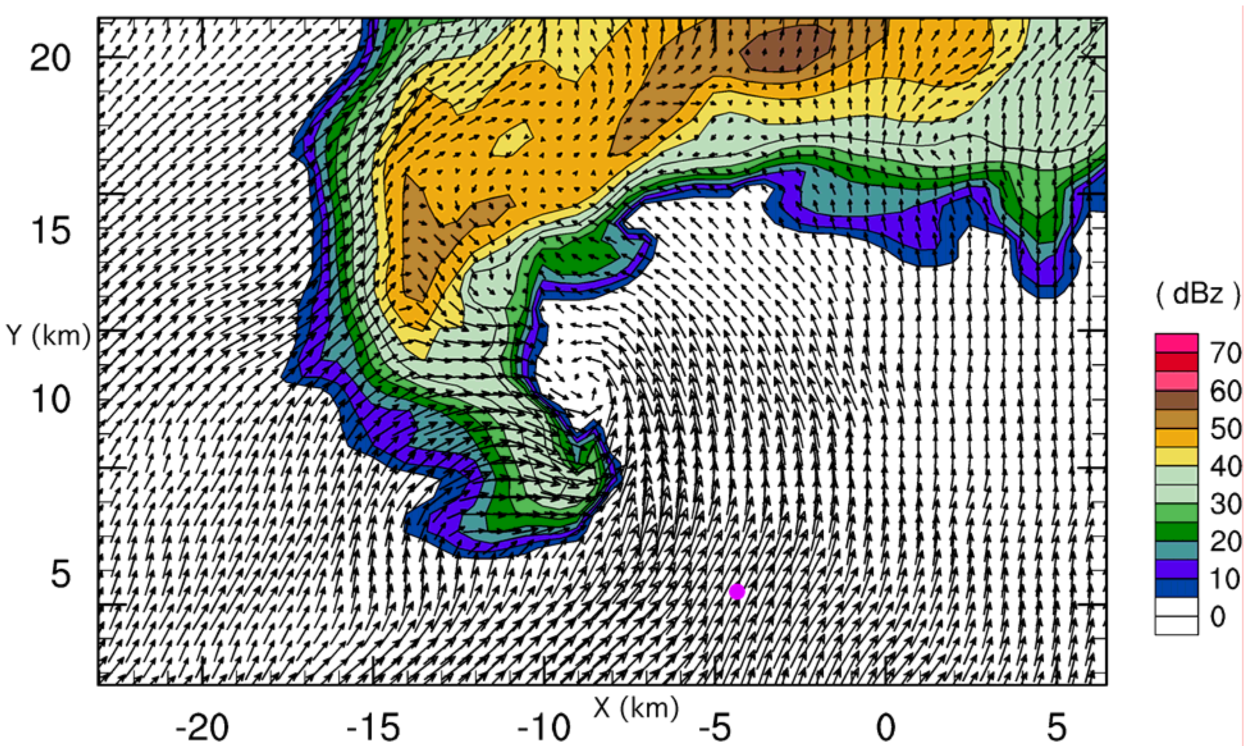
This project is ongoing.

Publications

Dowell, D. C., C. R. Alexander, J. M. Wurman, and L. J. Wicker, 2005: Reflectivity patterns and wind-measurement errors in high-resolution radar observations of tornadoes. *Mon. Wea. Rev.*, **133**, 15011524.

Burgess, D.W., D.C. Dowell, L.J. Wicker, and A. Witt, 2005: Detailed comparison of observed and modeled tornadogenesis. CD-ROM, *32nd Conf. on Radar Meteorology*, Albuquerque, NM, Amer. Meteor. Soc., Paper # 10R.4.





Low-level (350 m AGL) ground-relative wind vectors overlaid on reflectivity at 2206 UTC on 8 May 2003 for (top image) KTLX and TDWR dual-Doppler winds and TDWR 0.5o reflectivity, and (bottom image) numerical model winds and derived reflectivity. Dark colored circle in the bottom image is location of TDWR radar.

Investigation of Synoptic and Mesoscale Meteorological Processes Associated with Hazardous Weather – *Thunderstorm Electrification and Lightning Experiment (TELEX)*

MacGorman, **Rust** (primary – NSSL), **Schuur, Apostolakopoulos**

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: CIMMS Task II – NSSL Project 6 and NSF

Objectives
The scientific purpose of TELEX is to test and revise hypotheses concerning the interrelationships among the wind field, microphysical characteristics, electrical structure, and lightning of isolated severe storms and of large storm systems, with long term objectives to improve thunderstorm forecasts and warnings.

Accomplishments
TELEX (http://www.nssl.noaa.gov/projects/telex/index.html) is a five-year project, funded in part by the National Science Foundation. We are in year three, having completed the field phase in 2004 when several upgraded observing systems operated in central Oklahoma: the polarimetric modified WSR88D 10-cm wavelength Doppler radar (KOUN), the Oklahoma three-dimensional lightning mapping array (OK-LMA), the two SMART Radars, mobile environmental soundings, and a mobile laboratory for storm intercept and mobile ballooning with up to four balloon soundings being made simultaneously. Thirty-six instrumented-balloon flights, each with a GPS radiosonde and an electric field meter, were made in 2004 into storms during thirteen ballooning missions. (In the initial, smaller field deployment in 2003, seven missions with 14 flights were done.) In both years, the flights were into a variety of storm types, including multicellular storms, supercells with and without tornadoes, and mesoscale convective systems.

In FY2005, we have been concentrating on data quality control from all instrumentation and on undertaking a significant amount of analyses. An interactive 3-D display has been developed to visualize and analyze combined data sets. Several students are analyzing data for their MS degrees and one is working on her PhD degree. The improved instrumentation has provided the opportunity to investigate thunderstorm electrification and lightning in greater detail than before. Preliminary results have emerged and are being presented at several conferences. One example is a multicellular storm, which occurred on 28-29 June 2004. The maximum measured electric field magnitude exceeded 150,000 volts per meter, which is a very large electric field. Analyses of storm charge location using electric field vectors, obtained during the dissipating stage of the storm, indicates a positive charge layer below the 0 °C level, followed by a large negative layer just above the melting level. Another positive and negative layer follow this. Polarimetric radar signatures within the melting layer are being examined in the context of the electric field observations. Mapped lightning flashes are used to clarify and compare with the charge structure inferred from the electric field profile. In the intensifying stage of the storm and above the melting level, polarimetric variables suggest that diagnostic signals might be present. Some variables decreased at the cellular-updraft scale and preceded the initial lightning flash in the storm. The first six flashes were typical negative ground flashes. The concurrent polarimetric signature in question is associated with lofted raindrops that serve as nuclei for riming graupel upon glaciation. The signature was absent in nearby cells that did not produce lightning. After the initial convective pulse, a polarimetric graupel signature corresponds with descending initiation points and active charge regions seen in LMA data. The signatures in these independent data sources descend at the same rate, providing strong evidence of an active non-inductive charging process.

Other collaborative analysis projects include numerical models of storm electrification, along with the more typical model fields.

This project is ongoing.

Publications

Beasley, W. H., K. B. Eack, R. A. Roussel-Dupree, E. C. Bruning, W. D. Rust, and D. R. MacGorman, 2004. Observed contemporaneous electric-field pulses and X-ray bursts in a thunderstorm in relation to charge distribution, lightning channels, and CG flash occurrence. *Eos Trans. AGU*, Fall Meet. Suppl., Abstract AE53A-08.

Bruning, E. C., W. D. Rust, D. R. MacGorman, J. Straka, P. Krehbiel, and W. Rison., 2004. Polarimetric radar and electric field observations of a multicell storm. Eos *Trans. AGU*, Fall Meet. Suppl., Abstract AE41A-09.

MacGorman, D. R., D. Rust, E. Bruning, N. Ramig, I. Apostolakopoulos, T. Schuur, J. Straka, P. Krehbiel, B. Rison, and T. Hamlin, 2004. Lightning and electric field structure of a squall line during TELEX, 2004, *Eos Trans. AGU.* Fall Meet. Suppl., Abstract AE42A-05.

Rust, D., D. MacGorman, T. Schuur, E. Bruning, Stephanie Weiss, J. Straka, W. Rison, T. Hamlin, P. Krehbiel, M. Biggerstaff, and I. Apostolakopoulos, 2004. Overview of the 2003 and 2004 field program phases of the Thunderstorm Electrification and Lightning Experiment (TELEX). *Eos Trans. AGU*, Fall Meet. Suppl., Abstract AE41A-08.

Rust, D., D. MacGorman, T. Schuur, E. Bruning, Stephanie Weiss, J. Straka, W. Rison, T. Hamlin, and P. Krehbiel, 2004. Overview of the 2003 and 2004 field program phases of the Thunderstorm Electrification and Lightning Experiment (TELEX), CD-ROM, *22nd Conf on Severe Local Storms*, Hyannis, MA, Amer. Meteor. Soc.

Dotzek, N., R.M. Rabin, L.D. Carey, D.R. MacGorman**,** T.L. McCormick, N.W. Demetriades, M.J. Murphy, and R.L. Holle, 2005: Lightning activity related to satellite and radar observations of a mesoscale convective system over Texas on 7-8 April 2002. *Atmos. Res.*, **76**, 127-166.

TELEX balloon launch and subsequent observation in 2004.

Investigation of Synoptic and Mesoscale Meteorological Processes Associated with Hazardous Weather – *Thunderstorm Electrification Modeling*

Mansell (primary – CIMMS at NSSL)**, Ziegler, Straka, MacGorman, Kuhlman**

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: CIMMS Task II – NSSL Project 6 and NSF

Objectives

Gain insight into electrification and microphysical processes and lightning behavior of thunderstorms.

Accomplishments

A study on the sensitivity of storm charge structure to different formulations of microphysical charge separation revealed a need to predict the number concentration of small ice crystals. The microphysics package was therefore upgraded to include number concentration for ice crystals (columns and plates), small rimed crystals, cloud droplets, rain, and cloud condensation nuclei (CCN), based on previous work by Ziegler. The upgrade continues to be evaluated and is being used in work to simulate an inverted-polarity storm that occurred on 3 June 2000 in southwestern Nebraska.

Mansell served as a mentor for the 2005 National Weather Center REU program. Elise Johnson from Iowa State University examined data from the Oklahoma Lightning Mapping Array (LMA) for the 26 May 2004 supercell storm in central Oklahoma. A major result suggests that negative cloud-to-ground flash reports from the National Lightning Detection Network may be unreliable at low current (less than -15kA peak) and low multiplicity (1 or 2), at least for this supercell storm.

This project is ongoing.

Publications

Mansell, E. R., D. R. MacGorman, C. L. Ziegler, and J. M. Straka, 2005: Charge structure and lightning sensitivity in a simulated multicell thunderstorm. *J. Geophys. Res.*, **110**, D12101, doi:10.1029/2004JD005287.

Straka, J. M., and E. R. Mansell, 2005: A bulk microphysics parameterization with multiple ice precipitation categories. *J. Appl. Meteor.*, **44**, 445-466.

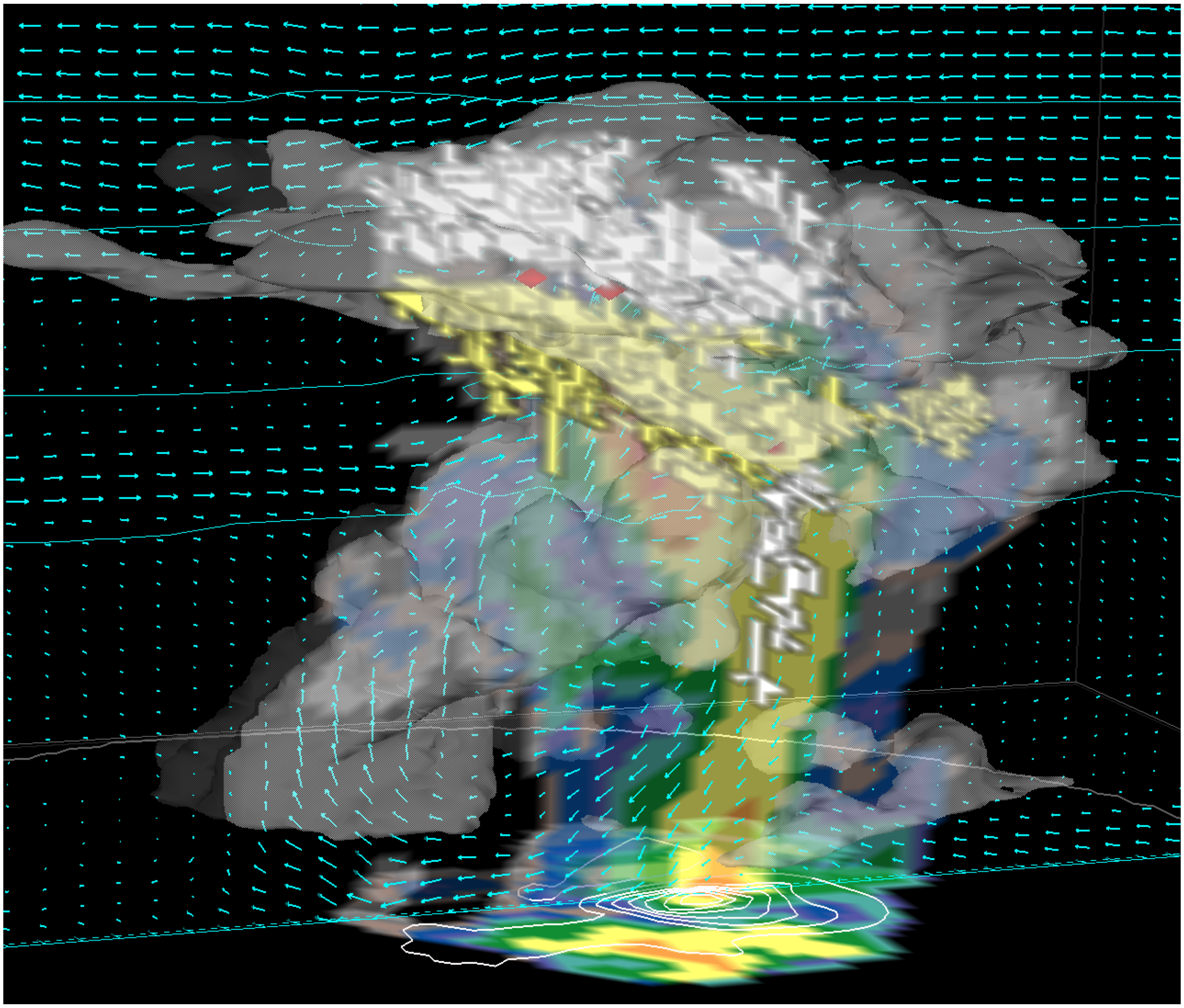
MacGorman, D. R., W. D. Rust, P. Krehbiel, W. Rison, E. Bruning, and K. Wiens, 2005: The electrical structure of two supercell storms during STEPS. *Mon. Wea. Rev.*, **133**, 2583–2607.

Lang, T. J., L. J. Miller, M. Weisman, S. A. Rutledge, L. J. Barker III, V. N. Bringi, V. Chandrasekar, A. Detwiler, N. Doesken, J. Helsdon, C. Knight, P. Krehbiel, W. A. Lyons, D. MacGorman, E. Rasmussen, W. Rison, W. D. Rust, and R. J. Thomas, 2004: The severe thunderstorm electrification and precipitation study. *Bull. Amer. Meteor. Soc.*, **85**, 1107-1125.

Rust, W. D., D. R. MacGorman, E. C. Bruning, S. A. Weiss, P. R. Krehbiel, R. J. Thomas, W. Rison, T. Hamlin, and J. Harlin, 2005: Inverted-polarity electrical structures in thunderstorms in the Severe Thunderstorm Electrification and Precipitation Study (STEPS). *Atmos. Res.*, **76**, doi: 10.1016/j.atmosres.2004.11.029, 247–271.

Kuhlman, K. M., C. L. Ziegler, E. R. Mansell, D. R. MacGorman, and J. M. Straka, 2005: Numerical simulations of the 29 June 2000 STEPS supercell: Microphysics, electrification, and lightning. *Mon. Wea. Rev.*, in review.

Fierro, A. O., M. S. Gilmore, E. R. Mansell, L. J. Wicker, J. M. Straka, and E. N. Rasmussen, 2005: Electrification and lightning in an idealized boundary-crossing supercell simulation of 2 June 1995. *Mon. Wea. Rev.*, in review.



Improved simulation of a small Florida thunderstorm with predicted number concentration of hydrometeors. Three lightning flashes are depicted. Negatively-charged lightning channels (white) indicate the upper main positive and lower positive ambient charge regions. Positively-charged lightning channels (yellow) indicate the main ambient negative charge region. The light gray surface denotes the simulated cloud boundary. The vertical electric field value at the surface is shown by white contour lines (intervals of 1 kV/m). Simulated reflectivity is shown at the surface and a vertical plane through the storm along with wind vectors. Wind vectors are spaced at 500m horizontally and 250m vertically. (The model resolution is 250m by 125m.) Cloud droplets form in the updraft on the left (west) side, and precipitation helps drive the downdraft. Cloud top height is about 9.8 km AGL. Isotherms are indicated by light blue contours (in plane of the vectors, from 0 to -40C in 10 degree increments).

Investigation of Synoptic and Mesoscale Meteorological Processes Associated with Hazardous Weather – ***Cold Frontal Research***
Schultz (primary – CIMMS at NSSL), Roebber

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: CIMMS Task II – NSSL Project 6

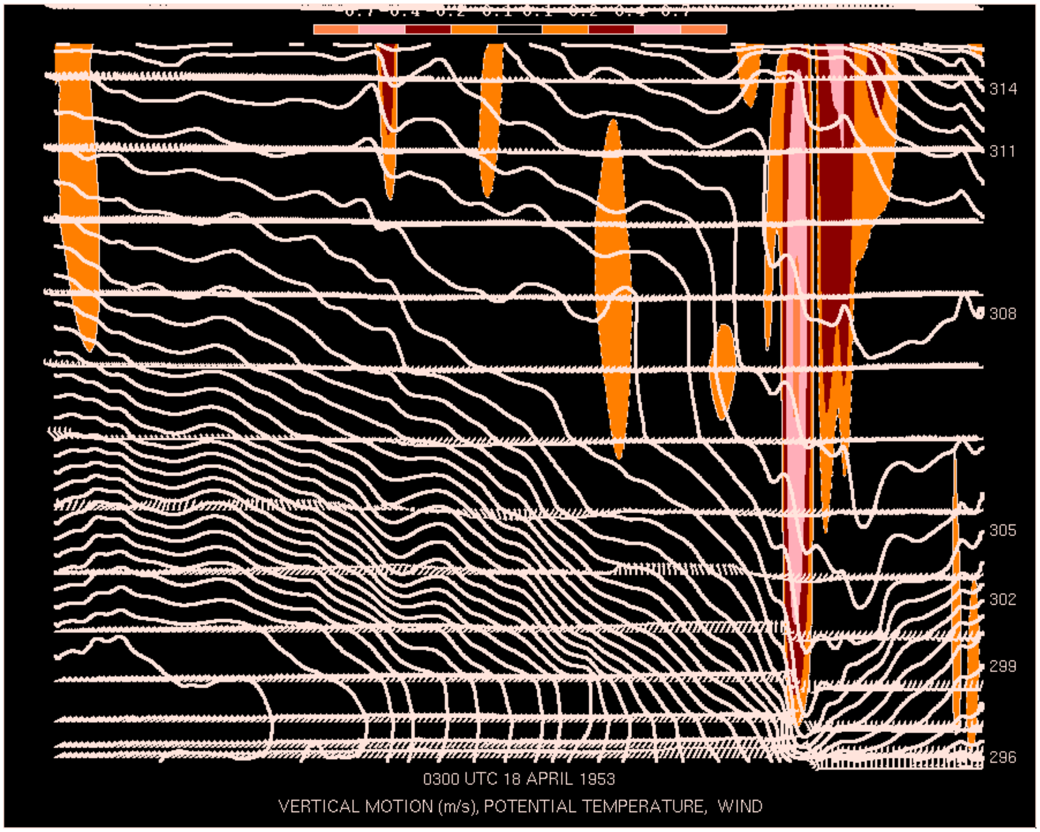
Objectives
Understand the processes acting in produce the variety of structures observed in cold fronts; review the mechanisms of prefrontal troughs.

Accomplishments
The conceptual model of a classical surface-based cold front consists of a sharp temperature decrease coincident with a pressure trough and a distinct wind shift at the surface. Many cold fronts, however, do not conform to this model – time series at a single surface station may possess a pressure trough and wind shift in the warm air preceding the cold front (hereafter called prefrontal trough and prefrontal wind shift, respectively). Although many authors have recognized these prefrontal features previously, a review of the responsible mechanisms has not been performed to date. This paper presents such a review. Ten disparate mechanisms with different frontal structures have been identified from the previous literature. These mechanisms include those external to the front (i.e., those not directly associated with the cold front itself): synoptic-scale forcing, interaction with lee troughs/drylines, interaction with fronts in the mid and upper troposphere, and frontogenesis associated with inhomogeneities in the prefrontal air. Mechanisms internal to the front (i.e., those directly associated with the structure and dynamics of the front) include: surface friction, frontogenesis acting on along-front temperature gradients, moist processes, descent of air, ascent of air at the front, and generation of prefrontal bores/gravity waves. Given the gaps in our knowledge about the structure, evolution, and dynamics of surface cold fronts, this paper closes with an admonition for improving the links between theory, observations, and modeling to advance understanding and develop better conceptual models of cold fronts, with the goal of improving both scientific understanding and operational forecasting.

Another component of this project was to examine the processes acting during the cold front of 17-18 April 1953, which was studied observationally by Sanders in 1955. Given that the 50th anniversary of the publication of this paper is this year, it was instructive to reexamine this cold front, given the context of 50 years of modern meteorological progress. A mesoscale model simulation was performed of the cold front, showing the sensitivity of the structure of the front and the magnitude of the vertical motion to the presence of an elevated mixed layer.

This project is ongoing.

Publications
Schultz, D. M., and P. J. Roebber, 2005: The 50th anniversary of Sanders (1955): A mesoscale-model simulation of the cold front of 17-18 April 1953. *The Fred Sanders Symposium Volume. Meteor. Monogr.*, Amer. Meteor. Soc., in press.
Schultz, D. M., 2005: Perspectives on Fred Sanders' research on cold fronts. *The Fred Sanders Symposium Volume. Meteor. Monogr.*, Amer. Meteor. Soc., in press.
Schultz, D. M., 2005: A review of cold fronts with prefrontal troughs and wind shifts. *Mon. Wea. Rev.*, **133**, 2449-2472.
Schultz, D. M., 2004: Cold fronts with and without prefrontal wind shifts in the central United States. *Mon. Wea. Rev.*, **132**, 2040-2053.
Roebber, P. J., D. M. Schultz, B. A. Colle, and D. J. Stensrud, 2004: Towards improved prediction: High-resolution and ensemble modeling systems in operations. *Wea. Forecasting*, **19**, 936-949.
Cohen, R. A., and D. M. Schultz, 2005: Contraction rate and its relationship to frontogenesis, the Lyapunov exponent, fluid trapping, and airstream boundaries. *Mon. Wea. Rev.*, **133**, 1353-1369.
Schultz, D. M., 2004: Historical research in the atmospheric sciences: The value of literature reviews, libraries, and librarians. *Bull. Amer. Meteor. Soc.*, **85**, 995-999.
Schultz, D. M., D. S. Arndt, D. J. Stensrud, and J. W. Hanna, 2004: Snowbands during the cold-air outbreak of 23 January 2003. *Mon. Wea. Rev.*, **132**, 827-842.



Cross section of the cold front presented in Sanders (1955), showing vertical motion (shaded), potential temperature (every 1 K), and wind barbs.

Investigation of Synoptic and Mesoscale Meteorological Processes Associated with Hazardous Weather – ***Mammatus Clouds: Observations, Mechanisms, and Modeling***
Schultz (primary – CIMMS at NSSL)**, Kanak, Straka,** Trapp, Gordon, **Zrnic, Kastner-Klein**, **Doswell,** Bryan, Lilly, Garrett

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: CIMMS Task II – NSSL Project 6

Objectives
Critically evaluate the mechanisms previously proposed in the literature to explain mammatus clouds; perform idealized modeling studies, in consultation with observations, of mammatus clouds.

Accomplishments
Theories describing mammatus clouds remain speculative as observations to quantitatively evaluate these theories do not exist because of their small distance scales and short times scales. Modeling studies designed to study mammatus are nonexistent. As a result, relatively little is known about the environment, origin, structure, size, microphysical properties, and dynamics of mammatus. This research begins with a review of mammatus clouds. This review raises questions about the formation mechanism for mammatus, the hydrometeors that comprise the mammatus, the size of the mammatus, and the reason for the smooth appearance of mammatus. The types of data that would need to be collected and numerical modeling experiments that would need to be performed to being to resolve these issues are proposed and the possibility of predicting mammatus is explored. Their appearance and formation remain an enigma and an intriguing problem of basic atmospheric fluid dynamics. This review aims to

summarize and clarify the understanding of the microphysics and dynamics of mammatus clouds and the environments in which they form, and to motivate others to study mammatus.

This project is ongoing.

Investigation of Synoptic and Mesoscale Meteorological Processes Associated with Hazardous Weather – *Investigating Convective System Propagation in Models that use Parameterized Convection*

Bukovsky (primary – CIMMS at NSSL), **Kain**, **Baldwin**

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: CIMMS Task II – NSSL Project 6

Objectives

Develop an understanding of the propagation mechanisms of mesoscale convective systems in NWP models that use parameterized convection and investigate whether this mechanism can be used to predict the evolution of MCSs more accurately.

Accomplishments

Bowing, propagating precipitation systems appear as prominent features in output from the Eta model (now called the NAM) and other models that use the Betts-Miller-Janjic (BMJ) convective parameterization, especially during the spring and early summer. These features often attract attention (especially among forecasters) because their shape and scale are similar to the leading convective line in bow echoes (see Fig. 1), which can be very destructive phenomena. This study provides an explanation for the origin, mechanism of upscale growth, and meteorological significance of these features.

Our work shows that their formation is a dynamic response to an unusual convective heating profile generated by the BMJ scheme in certain environments. The unusual characteristic of this profile is a heating/cooling dipole, with heating in the upper half of the parameterized cloud layer and cooling in the lower half, a profile which the BMJ scheme tends to produce in moist environments where high lapse rate layers exist well above the base of parameterized clouds. The strong cooling tendency in the lower half of cloud layer induces circulations that favor expansion of convective activity into nearby grid columns, which can lead to growing, self-perpetuating mesoscale systems under certain conditions.

The propagating characteristics of these systems have been examined and three contributing mechanisms of propagation have been identified. The mechanisms include a mesoscale downdraft induced by the deep lower-to-middle tropospheric cooling, a convectively induced buoyancy bore, and a boundary-layer cold pool that is indirectly produced by the convective scheme in this environment. Each of these mechanisms destabilizes the adjacent atmosphere and decreases convective inhibition in nearby grid columns, promoting new convective development, expansion, and propagation of the larger system.

Although these systems often appear in meteorological regimes that support real bowing systems, their correspondence with observed strongly propagating systems is typically poor, especially on the time and space scales that are important for regional weather prediction. Furthermore, forecasters often view them as spurious features, since they appear in model output much more frequently than bow echoes develop in reality. This high false-alarm rate limits their value as predictors of real bowing MCSs.

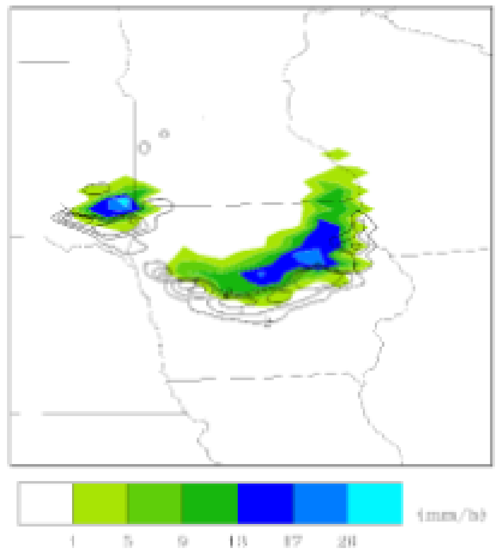
This project has been completed.

Publications

Bukovsky, M. S., and J. S. Kain, 2004: Predicting propagating convective systems using operational forecast models. CD-ROM, *22nd Conference on Severe Local Storms*, Hyannis, MA, Amer. Meteor. Soc., paper 17.7.

Bukovsky, M. S., J. S. Kain, and M. E. Baldwin, 2005: Bowing convective systems in a popular operational model: Are they for real? Preprints, *21st Conf. on Weather Analysis and Forecasting/17th Conf. on Numerical Weather Prediction*, Washington, D.C., Amer. Meteor. Soc., paper 2A.1.

Bukovsky, M. S., J. S. Kain, and M. E. Baldwin, 2005: Bowing convective systems in a popular operational model: Are they for real? *Wea. Forecasting*., accepted.



A bowing, propagating convective system in an Eta model forecast, as revealed by the surface precipitation rate (mm/h) and 700-hPa pressure vertical velocity (contours from -2 to -6 Pa s-1 with an interval of 2 Pa s-1) fields.

Investigation of Synoptic and Mesoscale Meteorological Processes Associated with Hazardous Weather – *Measurement and Analysis of the Preconvective Boundary Layer and Convection Initiation during IHOP*

Ziegler (primary – NSSL), **Rasmussen**, **Buban**

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: CIMMS Task II – NSSL Project 6 and NSF

Objectives
Determine conditions for initiation of convective storms, cumulus formation, or suppression of moist convection; test hypothesis that moist air rising in mesoscale boundary layer updrafts must achieve its LCL (LFC) prior to leaving the updraft to form cumuli (storms).

Accomplishments
Analyses of the 22 May and 24 May 2002 IHOP cases (early stages reported in FY04 CIMMS report) have been completed, and findings are being disseminated. Three formal manuscripts are in review (Ziegler et al. 2005a, Ziegler et al. 2005b, Buban et al. 2005), oral presentations on each case are in preparation for the 11th Mesoscale Conference in Albuquerque, NM (Buban et al. 2005, Ziegler et al. 2005c), and M. Buban will defend his M.S. thesis during the Fall 2005 semester (Buban 2005). An oral presentation on application of an expanded version of the Lagrangian technique including diabatic terms in the precipitation-filled boundary layer of the Newcastle, Texas storm (29 May 1994 during VORTEX) is in preparation for the 32nd Conference on Radar Meteorology in Albuquerque, NM (Ziegler et al. 2005d).

The studies are based on a new Lagrangian in-situ data objective analysis technique that assimilates in-situ boundary layer (BL) data and mixed layer profiles ("grid-column" soundings) in mesoscale updrafts with dense, time-spaced 3-D input multi-Doppler wind fields. The basis of the Lagrangian method is the upstream and downstream propagation of conservative variables from each in-situ and grid-column sounding data point, with subsequent Barnes space-time interpolation of the dense Lagrangian data to the input 3-D radar wind synthesis grid. The figure shows resultant vertical cross-sections of winds and the Lagrangian water vapor mixing ratio analyses through the 22 May dryline (top panel) and the 24 May cold front and dryline (bottom panel). In the 24 May case, LCL height is within the radar analysis domain, water saturation is achieved in mesoscale updrafts, and cumuli are diagnosed to the east of the dryline and just behind the strong cold front.

This project is ongoing.

Publications

Buban, M., C. Ziegler, E. Rasmussen, and Y. Richardson, 2005: The dryline on 22 May 2002 during IHOP: Ground-radar and in-situ data analyses of the dryline and boundary layer evolution. *Mon. Wea. Rev.*, in review.

Ziegler. C., E. Rasmussen, M. Buban, Y. Richardson, L. J. Miller, and R. Rabin, 2005: The "Triple Point" on 24 May 2002 during IHOP. Part II: Ground-radar and in-situ boundary layer analysis of cumulus development and convection initiation. *Mon. Wea. Rev.*, in review.

Ziegler, C., M. Buban, and E. Rasmussen, 2005: A Lagrangian thermodynamic analysis technique for assimilating in-situ observations in multiple radar-derived airflow. *Mon. Wea. Rev.*, in review.

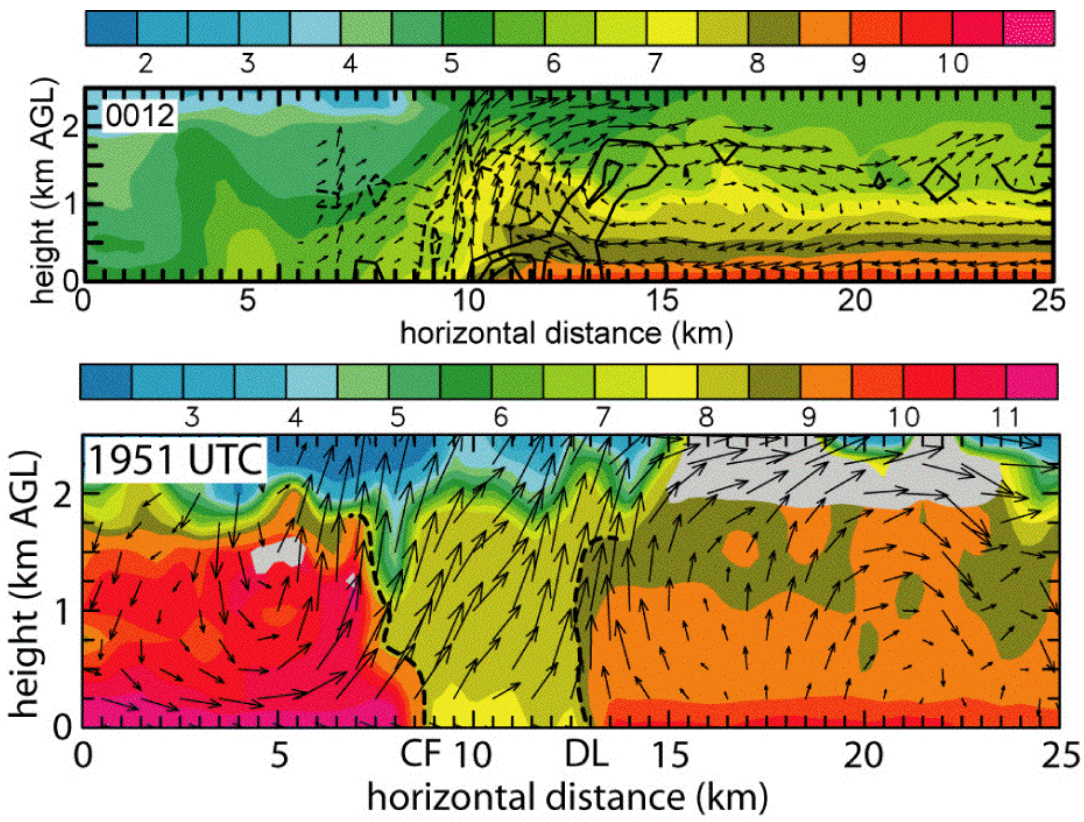
Buban, M., C. Ziegler, E. Rasmussen, and Y. Richardson, 2005: CD-ROM, *11th Conf. on Mesoscale Processes*, Amer. Meteor. Soc.

Ziegler, C., E. Rasmussen, M. Buban, Y. Richardson, L. J. Miller, and R. Rabin, 2005: CD-ROM, *11th Conf. on Mesoscale Processes*, Amer. Meteor. Soc.

Ziegler, C., E. Rasmussen, and M. Buban, 2005: Radar-derived thermodynamic fields in severe storms from in-situ data and Lagrangian objective analysis. CD-ROM, *32nd Conf. on Radar Meteorology*, Amer. Meteor. Soc.

Buban, M., 2005: The dryline on 22 May 2002 during IHOP: Ground-radar and in-situ data analyses of the dryline and boundary layer evolution. M.S. Thesis, Univ. of Oklahoma, Norman, 100 pp.

Brown, R. A., B. A. Flickinger, E. Forren, D. M. Schultz, D. Sirmans, P. L. Spencer, V. T. Wood, and C. L. Ziegler, 2005: Improved detection of severe storms using experimental high-resolution WSR-88D measurements. *Wea. Forecasting*, **20**, 3-14.



Radar and Lagrangian analyses in vertical cross-sections normal to boundaries from IHOP-2002 observations. Top panel: 22 May 2002 dryline (DL located at x = 10 km); bottom panel: 24 May 2002 cold front-dryline "triple point" case. Vector airflow in the plane is overlaid on Lagrangian water vapor mixing ratio (g kg-1) field. Color bars indicate fill values (g kg-1). Gray fill in bottom panel (24 May case) indicates areas of water saturation (i.e. cumulus). In top panel, contours are vertical vorticity (2 x 10-3 s-1 contour interval, solid contour > 0).

Dynamics of Hurricanes at Landfall

Biggerstaff (at OU School of Meteorology)

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: CIMMS Task II

Objectives

Determine the three-dimensional structure of hurricane wind and precipitation fields during landfall; provide high quality data sets to aid validation of numerical simulations of land-falling tropical cyclones; diagnose the impact of mesoscale and convective-scale processes on the distribution of heavy rains and floods from land-falling tropical cyclones.

Accomplishments

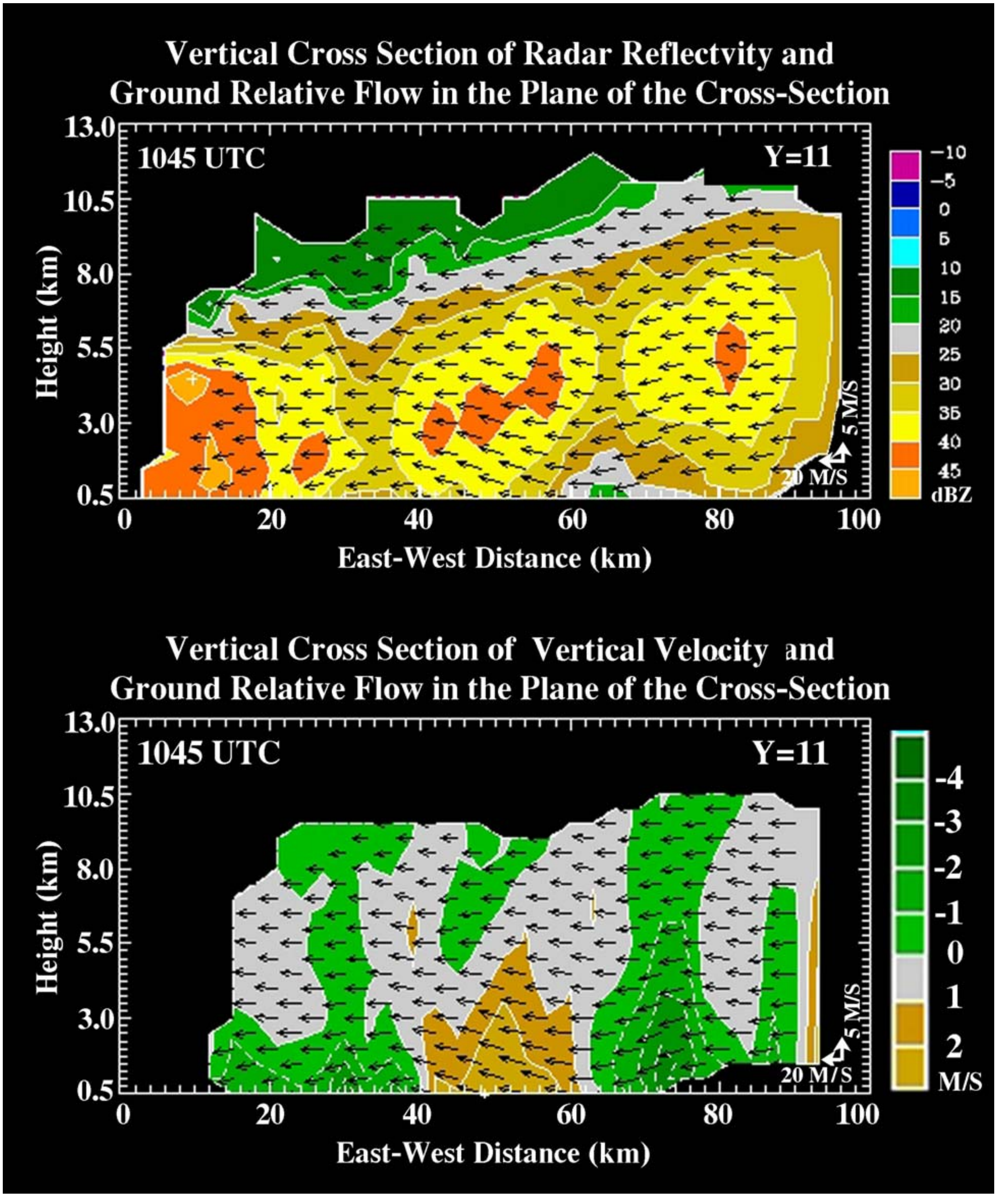
Several dual-Doppler analyses have been performed of outer rainbands associated with the landfall of Hurricane Isabel that occurred on 18 September 2003 in North Carolina. The data had been collected by the Shared Mobile Atmospheric Research and Teaching (SMART) radar deployment conducted in the previous year. It was determined that the interaction with flow over the land may have contributed to a two-branch circulation with subsiding easterly flow in the northern branch and rising northeasterly flow in the southern branch of the circulation. Highest reflectivity and heaviest surface rainfall was associated with the rising branch. Also, the interaction of hurricane rainbands with a frontal zone was diagnosed. The frontal circulation contributed to a broad region of ascent from low-to-mid levels just offshore. However, the air rising over the frontal boundary had already been modified by nearby rainbands and likely did not contribute significantly to the overall production of precipitation.

Also, a joint field experiment was conducted with Texas Tech University into Hurricane Frances that made landfall in Florida on 5 September 2004. More than 14 hours of continuous data were collected to examine the structure of boundary-layer rolls and their possible impact on damaging surface winds. Numerous tornadic cells were sampled by the SMART radars.

This project is ongoing.

Publications

Curry, R. and M. I. Biggerstaff, 2005: Dual-Doppler analysis of Hurricane Isabel at landfall: A Research Experience for Undergraduates. CD-ROM, *32nd Conf. on Radar Meteorology*, Albuquerque, NM, Amer. Meteor. Soc.



Vertical cross-section through outer rainbands of Hurricane Isabel at 1045 UTC 18 September 2005. The radar bright band descends from 5 km to 2.7 km altitude over a 20 km distance (between 60-40 km) across the frontal zone where low-level ascent of 2-3 m s-1 was found.

Role of Storm Dynamics on Cloud Electrification

Biggerstaff (primary – OU School of Meteorology)**, MacGorman, Rust, Schuur**

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: CIMMS Task II and NSF

Objectives

Determine the relationship between storm dynamics and the frequency, polarity, location, and amplitude of in-cloud and cloud-to-ground lightning in mesoscale convective systems and supercell thunderstorms.

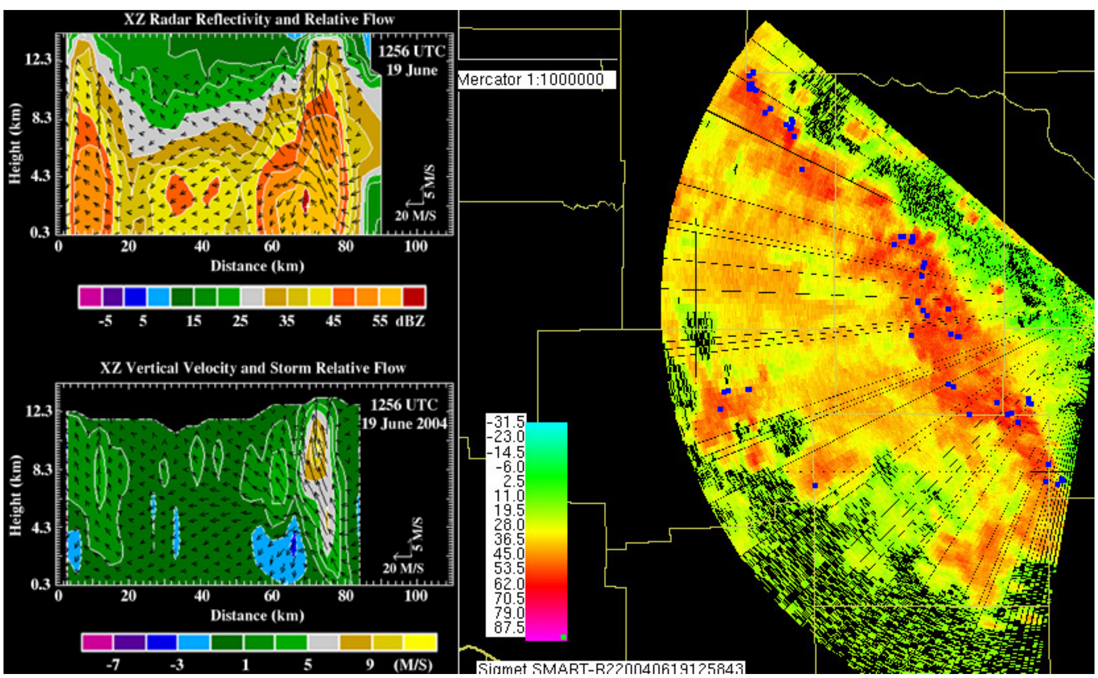
Accomplishments

Several dual-Doppler analyses were performed of the 19 June 2004 leading-line trailing-stratiform squall-line that was sampled by the SMART radars as it crossed central Oklahoma. It has been determined that the flash rate over the convective region deceased by nearly 70% during the first 30 minutes of the data collection period. This decrease was accompanied by a nearly 8 dB decrease in area-averaged radar reflectivity and by a 30-40% reduction in the mean upward motion at mid-to-upper levels where charge generation and separation takes place. Based on a preliminary analysis of a subset of the lightning initiation and termination locations provided by a three-dimensional lightning mapping system, found that none of the flashes originated in the stratiform region despite several cloud-to-ground strikes occurring in the stratiform region.

This project is ongoing.

Publications

Biermann, N. S., M. I. Biggerstaff, G. D. Carrie, N., R. Ramig, T. L. Wiegman, M. L. Sessing, D. R. MacGorman, W. D. Rust, L. D. Carey, P. R. Krehbiel, W. R. Rison, and T. Hamlin, 2005: The role of storm dynamics on lightning activity for the 19 June 2004 Mesoscale Convective System during TELEX. CD-ROM, *32nd Conf. on Radar Meteorology,* Albuquerque, NM, Amer. Meteor. Soc.



Vertical cross-section of radar reflectivity and vertical motion through the 19 June 2004 MCS (left side) and location of flash initiation points relative to the low-level radar reflectivity for flashes occurring between 1258 and 1300 UTC (right side).

Concentrating Vorticity near the Ground: Investigation of Supercell Rear-Flank Precipitation, Vorticity Generation, and Transport Processes

Rasmussen (primary – CIMMS at OU)**, Straka,** Gilmore, **Davies-Jones**

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: NSF

Objectives

Gain an understanding of the processes that operate in the rear flank region of supercell thunderstorms and are responsible for tornado formation.

Accomplishments

Work has been completed to examine all of the published historical dual-Doppler analyses of supercell thunderstorms. This examination demonstrated that all of these cases featured near-ground counter-rotating vortices. This finding is in contrast to the pervasive focus on only the cyclonic member (mesocyclone) in the literature. A simple numerical simulation was performed that replicates many of the observed rear-flank features, including the counter-rotating vortices, and a downdraft nestled within the rear side of a horseshoe-shaped updraft. These features can be simulated, without ambient shear, simply by embedding a rainy downdraft in the rear of the updraft. The implication is that some of the important processes for tornadogenesis may have little explicit dependence on environmental shear, but may have dependence on the occurrence of a localized downdraft in the rear of the supercell updraft.

Concurrent research is being conducted on the climatological prevalence of the descending reflectivity maximum that occurs at the rear flank of many supercell storms. It is thought that this localized precipitation feature may induce the local downdraft mentioned above, promoting tornado formation.

This project is ongoing.

Publications

Rasmussen, E. N., and J. M. Straka, 2005: Evolution of low-level angular momentum in the 2 June 1995 Dimmitt, Texas tornado cyclone. *J. Atmos. Sci.*, in review.

Rasmussen, E. N., J. M. Straka, M. S. Gilmore, and R. Davies-Jones, 2005b: A survey of the occurrence of rear-flank descending reflectivity cores in a small sample of supercell storms. *Wea. Forecasting*, in review.

Straka, J. M., E. N. Rasmussen, and K. M. Kanak, 2005: An examination of low-level counter-rotating vortices in the rear flank of supercells. *J. Atmos. Sci.*, submitted.

Straka, J. M., M. S. Gilmore, E. N. Rasmussen, and K. M. Kanak, 2005: A comparison of the conservation of number concentration for the continuous collection and vapor diffusion growth equations using one- and two-moment methods. *J. Appl. Meteor.*, in review.

——, 2004b: Precipitation uncertainty due to variations in precipitation particle parameters within a simple microphysics scheme. *Mon. Wea. Rev.*, **132**, 2610-2627.

Gilmore, M. S., J. M. Straka, and E. N. Rasmussen, 2004a: Precipitation and evolution sensitivity in simulated deep convective storms: Comparisons between liquid-only and simple ice and liquid phase microphysics. *Mon. Wea. Rev.*, **132**, 1897-1916.

Gilmore, M.S., J. M. Straka and E. N. Rasmussen, 2004: Precipitation Uncertainty Due to Variations in Precipitation Particle Parameters within a Simple Microphysics Scheme. *Mon. Wea. Rev.*, **132**, 2610-2627.

Lang, T. J., L. J. Miller, M. L. Weisman, S. A. Rutledge, L. J. Barker, III, V. N. Bringi, V. Chandrasekar, A. Detwiler, N. Doesken, J. Helsdon, C. Knight, P. Krehbiel, W. A. Lyons, D. R. MacGorman, E. N. Rasmussen, W. Rison, W. D. Rust, and R. J. Thomas, 2004: The severe thunderstorm electrification and precipitation study (STEPS). *Bull. Amer. Meteor. Soc.*, **84**, 1807-1826.

Pietrycha, A. E. and E. N. Rasmussen, 2004: Finescale surface observations of the dryline: a mobile mesonet perspective. *Wea. Forecasting*, **19**, 1075-1088.

Ziegler, C., D. Kennedy, and E. N. Rasmussen, 2004: A wireless network for collection and synthesis of mobile mesoscale weather observations. *J. Atmos. Oceanic Technol.*, **21**, 1659-1670.

Numerical Simulations of Derecho-Producing Convective Systems

Stensrud (primary – NSSL)**,** Coniglio**, Richman**

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: NSF

Objectives

Improve our understanding of the mechanisms that develop and sustain mesoscale convective systems (MCSs) that produce widespread windstorms, known as derechos; explore the underemphasized role of upper-level vertical wind shear on these systems by producing a set of idealized numerical cloud model simulations.

Accomplishments

Past CIMMS supported research has shown that strong midlatitude MCSs tend to decay as they move into environments with less instability and smaller deep-layer shear. These observations are somewhat different from the low-level shear profiles considered favorable for strong, long-lived convective systems in some past idealized simulations. Thus, to explore the role of upper-level shear in strong-MCS environments, a set of two-dimensional (2D) simulations of density currents within a dry, statically neutral environment are used to quantify the ability of an idealized cold pool to lift environmental air within a vertically sheared flow. A set of three-dimensional (3D) simulations of MCSs in varying upper-level shear is produced to gauge the consistency between the idealized 2D simulations and 3D simulations in a more realistic framework and to document the effects of upper-level shear on MCS structure and longevity.

Results confirm that the addition of upper-level shear to a wind profile with weak to moderate low-level shear increases the vertical displacement of low-level parcels despite a decrease in the vertical velocity along the cold pool interface. Parcels that are elevated above the surface (1-2 km) overturn and are responsible for the deep lifting in the deep-shear environments, while the low-level parcels typically pass through the cold pool region in a rearward-sloping path. This deep overturning helps to maintain the leading convection and greatly increases the size and total precipitation output of the convective systems in more complex 3D simulations, even in the presence of 3D structures. These results show that the shear profile throughout the entire troposphere must be considered to gain a more complete understanding of the structure and maintenance of strong midlatitude MCSs. These concepts were used as a basis for developing a forecasting tool for the maintenance of strong, quasi-linear convective systems. This forecasting tool was recently tested during the 2005 Summer Program held at the Storm Prediction Center under the auspices of the NOAA Hazardous Weather Testbed.

This project has been completed.

Publications

Coniglio, M.C., D.J. Stensrud, and L.J. Wicker, 2005: Role of upper-level shear on the structure and maintenance of strong quasi-linear mesoscale convective systems. *J. Atmos. Sci.*, accepted.

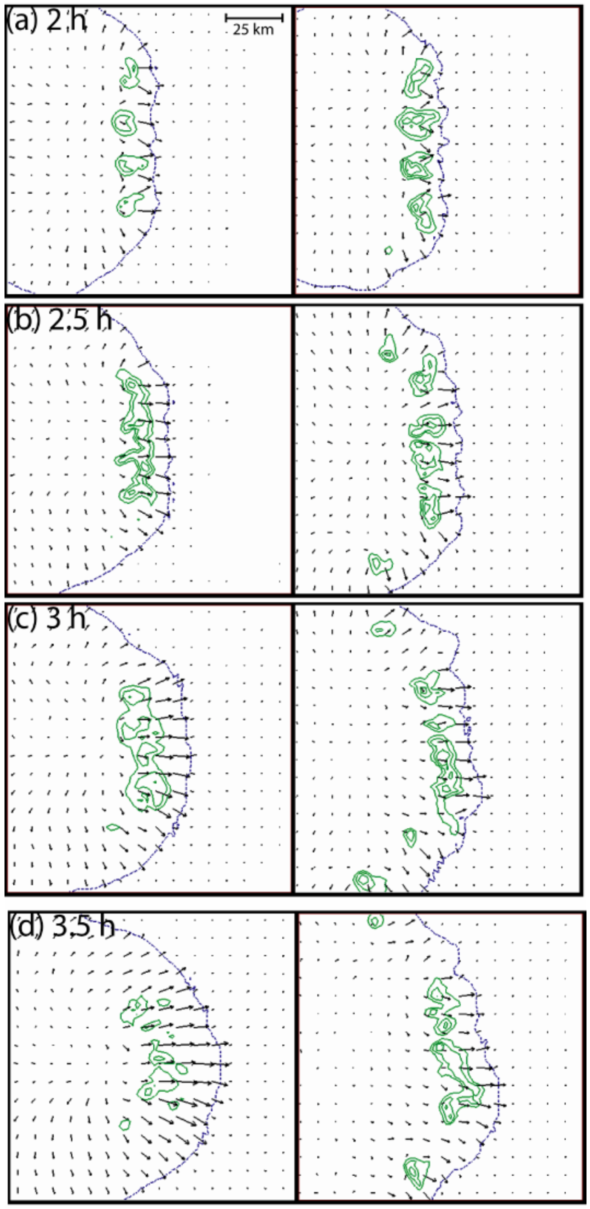
Stensrud, D.J., M.C. Coniglio, R.P. Davies-Jones, and J.S. Evans, 2005: Comments on "A Theory for Strong Long-Lived Squall Lines" Revisited. *J. Atmos. Sci.*, **62**, 2989-2996.

Segele, Z. T., D. J. Stensrud**,** I. C. Ratcliffe, and G. M. Henebry, 2005: Influence of a hailstreak on boundary layer evolution. *Mon. Wea. Rev.*, **133**, 942-960.

Coniglio, M.C.**,** D.J. Stensrud, and M.B. Richman, 2004: An observational study of derecho-producing convective systems. *Wea. Forecasting*, **19**, 320-337.

Coniglio, M.C., and D.J. Stensrud, 2004: Interpreting the Climatology of Derechos. *Wea. Forecasting*, **19**, 595-605.

Coniglio, M.C., D.J. Stensrud, and L.W. Wicker, 2004: How upper-level shear can promote organized convective systems. CD-ROM, *22nd Conf. on Severe Local Storms*, Amer. Meteor. Soc., Hyannis, MA., paper 10.5.



Evolution of the surface total precipitation mixing ratio (solid lines every 2 g kg-1 starting at 2 g kg-1) that highlights the heaviest precipitation, the position of the gust front at the surface (dashed line) and the ground relative wind vectors at the surface (every 4 grid points) for a 120 km by 120 km portion of the domain at (a) 2 h, (b) 2.5 h, (c) 3 h, and (d) 3.5 h for the simulation with no upper-level shear (left panels) and for the simulation with 15 m s-1 of upper-level shear (right panels).

Study of the Genesis, Evolution, Structure, and Dynamic Climatology of Tornadoes and Their Environments: Radar-Based Climatology of Tornado Structure and Dynamics

Alexander (primary – OU School of Meteorology)**, Biggerstaff, Carr, Dowell**, Murphy, **Shapiro, Wicker,** Wurman

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: NSF

Objectives

Construct a tornado climatology based upon high resolution radar observations of tornado structure including: 1) quantifying the means, distributions and (co)variances of kinematic properties (velocities, vorticity, divergence, wavenumbers etc.) in tornadoes, and 2) providing a calibration to the Fujita scale by comparing frequency distributions of radar-based and damage-based tornado intensity estimates.

Accomplishments

During the past year, I have continued work on my PhD research, and I successfully completed my General Examination in December 2004 where I presented my research prospectus. Some initial results of my research into a Radar-Based Climatology of Tornado Structure and Dynamics were presented along with a proposed methodology for analyzing all the cases in the data set. I have inventoried all of the tornado radar data sets (about 100 total) collected by the Doppler On Wheels (DOW) over the past ten years.

I presented a comparison of 12 DOW tornado data sets and WSR-88D mesocyclonic data at the American Meteorological Society's 22nd Conference on Severe Local Storms in October 2004. This comparison also included some common characteristics of tornado structures observed with the DOW tornado data. A poster was also presented comparing radar tornado signatures from the DOWs to other simulated radar platforms including the WSR-88Ds, SMART-Radars, ELDORA, and CASA radars.

I have continued to develop DORADE (mobile radar data platform) software algorithms to help with noise reduction, dealiasing, and locating centers of circulation. The algorithms have been applied to several DOW cases to help classify and characterize the tornado data set for the construction of the climatology.

I also helped draft and submit a three-year research proposal to the National Science Foundation (NSF) as a co-principle-investigator in May 2004 entitled: Collaborative Research: Study of the Genesis, Evolution, Structure, and Dynamic Climatology of Tornadoes and Their Environments. The proposal was recently funded.

This project is ongoing.

Publications

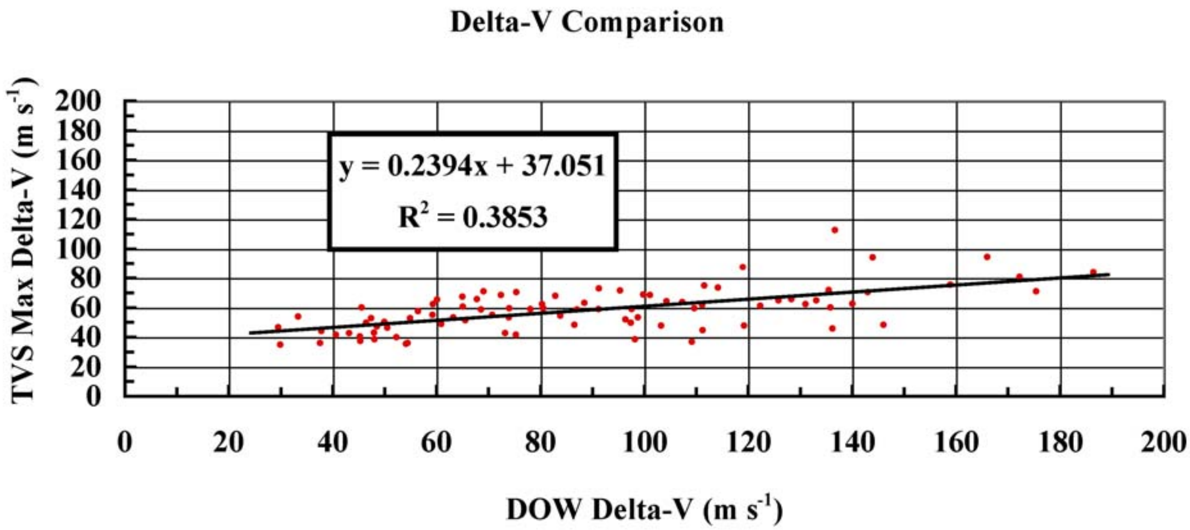
Alexander, C. R., and J. Wurman, 2005: The 30 May 1998 Spencer, South Dakota, storm. Part I: The structural evolution and environment of the tornadoes. *Mon. Wea. Rev.*, **133**, 72-96.

Wurman, J., and C. R. Alexander, 2005: The 30 May 1998 Spencer, South Dakota, storm. Part II: Comparison of observed damage and radar-derived winds in the tornadoes. *Mon. Wea. Rev.*, **133**, 97-119.

Dowell, D. C., C. Alexander, J. Wurman, and L. Wicker, 2005: Centrifuging of hydrometers and debris in tornadoes: Radar-reflectivity patterns and wind-measurements errors. *Mon. Wea. Rev.*, **133**, 1501-1524.

Wurman, J., and C. Alexander, 2004: Scales of motion in tornadoes. What radars cannot see. What scale circulation is a tornado. CD-ROM, *22nd Conf. on Severe Local Storms,* Hyannis, MA, Amer. Meteor. Soc., P11.6.

Alexander, C., and J. Wurman, 2004: Comparison between DOW observed tornadoes and parent mesocyclones observed by WSR-88Ds. CD-ROM, *22nd Conf. on Severe Local Storms*, Hyannis, MA, Amer. Meteor. Soc., P13.4.



Correlation between WSR-88D Max TVS velocity difference and DOW velocity difference for 12 strong tornadoes.

Effects of Multi-Dimensional Radiative Transfer on Cloud System Evolution
Mechem (primary – CIMMS at OU), **Y. Kogan**

NOAA Strategic Goal 2 *(Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond)*

Funding Agency: U.S. DOE

Objectives
Assess the importance of horizontal radiative transfer on the evolution of radiatively-forced PBL clouds.

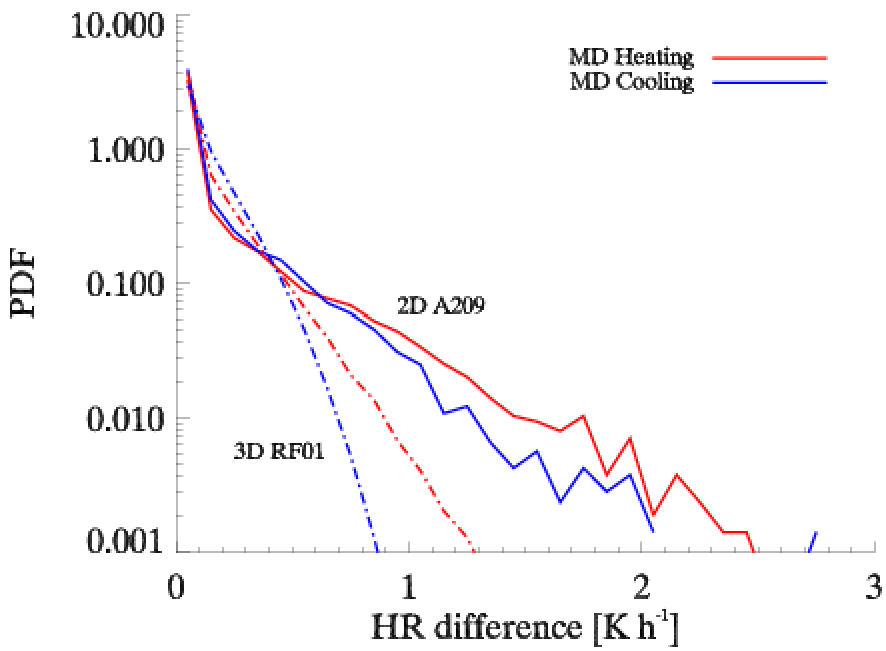
Accomplishments
Calculations of cloud top thermal IR radiative forcing demonstrate significant differences between whether full multi-dimensional (MD) or one-dimensional (1D) radiative transfer (RT) is employed. We explore the relationship between MD and 1D forcing by applying the RT scheme of Evans (19998) on cloud fields generated by the CIMMS Large Eddy Simulation model (LES). Although the geometry of stratocumulus clouds is highly constrained by a temperature inversion, close inspection of cloud top structure shows peaks and valleys on the order of a few tens of meters. The primary differences in cloud top cooling rates between MD and 1D RT arise in regions of this complicated cloud top geometry. Cooling rates are weaker in the downward undulations of cloud top ("valleys") and stronger in the upward undulations ("billows"). Probability distribution functions of the MD-1D cooling rate differences show that anomalous warming in the valleys is slightly greater than anomalous cooling over the billow regions, resulting in a weak net reduction in overall radiative forcing.

The interactive MD effect is evaluated through coupling the LES with the MDRT scheme in a 2D framework. Recent results tend to confirm more rigorously our previous conclusions that MD effects on the evolution of cloud field statistics were relatively minor and that a 1D treatment of RT is sufficient. Two caveats were identified. First, because of the peculiarities of 2D turbulent flow, LES cloud fields generated by 2D simulations sometimes overestimate cloud top variability, resulting in an unrealistically strong MD RT effect. The overly energetic turbulent flows associated with these cases could generally be mitigated through judicious tuning of the grid aspect ratio. In addition, recent simulations have brought to light the importance of calculating RT more frequently. Simulations performed using an interval of 40 s show that by the end of the interval, the cooling rates become so decorrelated from the cloud field and underlying dynamics that any subtle MD signal that might be present is not produced in the simulation. Using a much shorter interval of 10 s alleviates this problem, at considerable computational expense however.

This project is ongoing.

Publications

Mechem, D. B., M. Ovtchinnikov, Y. L. Kogan, K. F. Evans, A. B. Davis, R. F. Cahalan, E. E. Takara, and R. G. Ellingson, 2004: Multi-dimensional longwave radiative forcing of PBL cloud systems. Proc., *14th International Conference on Clouds and Precipitation*, Bologna, Italy, International Commission on Clouds and Precipitation, 1533-1536.



Probability distribution functions of the difference between MD and IPA heating rates for a 2D ASTEX A209 (solid) and 3D DYCOMS-II RF01 (dashed) simulations. Red lines indicate the portion of the PDF where the MD cloud top cooling is weaker than the 1D; blue lines indicate regions where the MD cooling is stronger than the 1D.

Turbulence Structure of Cold Season Continental Stratocumulus

Mechem (primary – CIMMS at OU), **Y. Kogan**

NOAA Strategic Goal 2 *(Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond)*

Funding Agency: U.S. DOE

Objectives

Explore the turbulence structure and diurnal variability of continental cloud-topped boundary layers using millimeter-wave cloud radar.

Accomplishments

Marine stratocumulus are an important regulator of the global shortwave radiation budget and have been extensively studied in field campaigns, numerical simulations, and theoretical modeling. Relatively few studies, however, have explored the turbulent properties of continental stratocumulus, which frequently occur over the postfrontal regions of midlatitude synoptic systems. We use a vertically pointing, 35 GHz

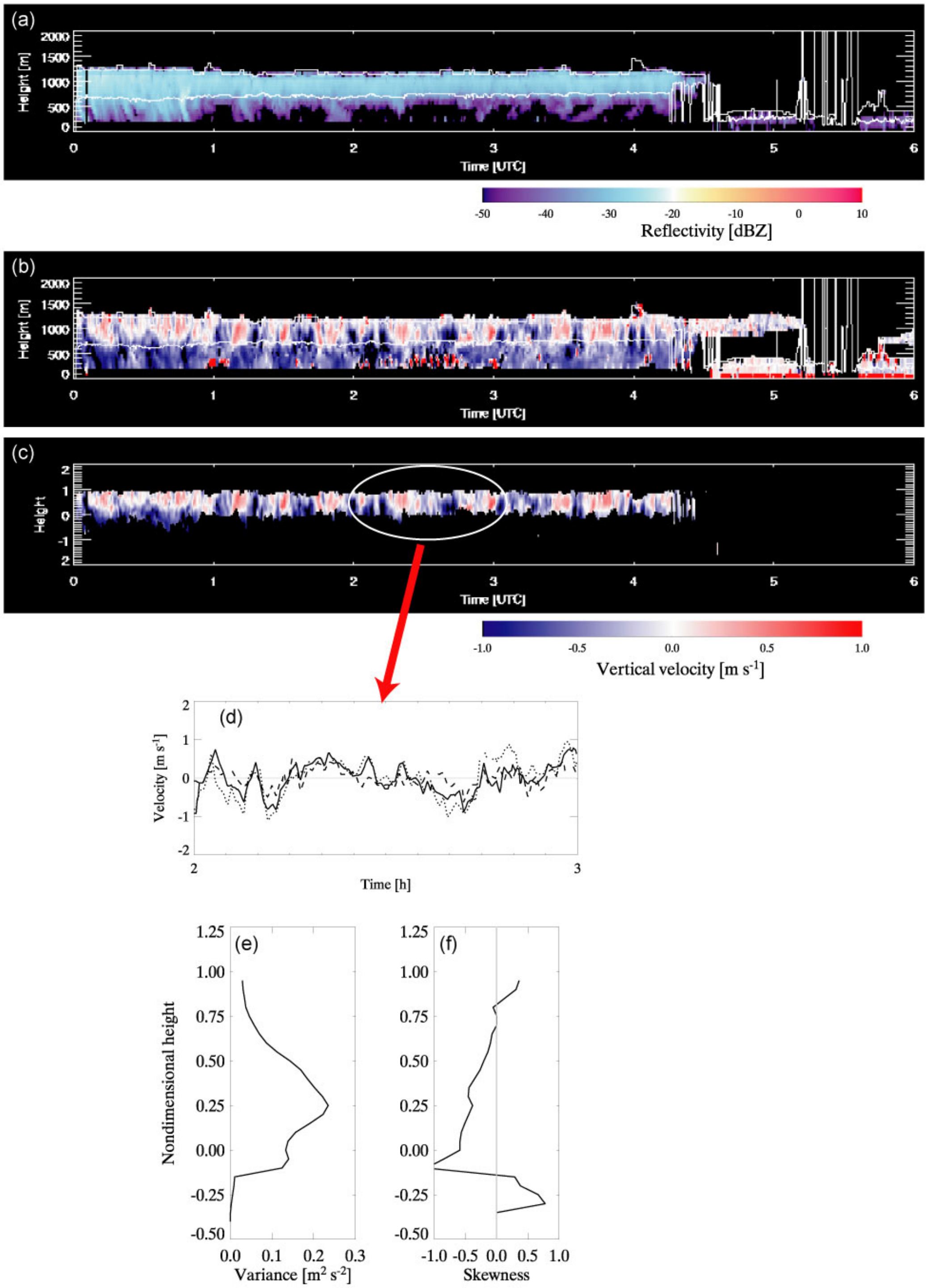
Millimeter-wave Cloud Radar (MMCR) operated at the Atmospheric Radiation Measurement Program Climate Research Facility (ACRF) to characterize the turbulent structure of continental stratocumulus. A combination of data from the MMCR, a Belfort laser ceilometer, and a micropulse lidar are incorporated into a value added product that identifies cloud boundaries. Based on cloud top height and a column maximum reflectivity threshold, seven months of cold season MMCR data were processed to identify non-precipitating boundary layer cloud segments. The vertical coordinate is transformed from geometric height to a non-dimensional height normalized by cloud boundaries, giving the advantage of being able to compare different cases in the same framework.

Several hours of stratocumulus coverage followed a frontal passage on 29 March 2001. As for most of these cases, the thermodynamic structure shows a well mixed subcloud layer and a moist adiabatic cloud layer topped by the inversion. Time series of vertical velocity at three levels in the cloud demonstrate remarkable coherence in vertical structure and time, especially considering the sampling strategy of the radar is not optimized for high-resolution measurements of PBL turbulence. Updraft and downdraft maxima are weaker than in the few previous examples of continental stratocumulus. We speculate that the prevalence of elevated cirrus layers that accompany these cloud systems enhance the downwelling longwave flux and reduce the jump in longwave flux across the cloud top interface. Mean profiles of vertical velocity variance and skewness show a well-mixed cloud layer but decreasing variance in the lower part of the cloud, possibly indicative of decoupled cloud and subcloud layer circulations. The magnitude of the variance is smaller than for previous continental cases, likely the result of the smaller velocity magnitudes. Skewness over the cloud layer is slightly negative, implying the predominance of strong, narrow downdrafts associated with cloud-top cooling. The skewness profile is consistent with the absence of shortwave forcing in this case. A wide case-to-case variability in turbulent intensity is apparent, but compositing the data into 24 hourly bins shows very little diurnal variability in cloud-mean velocity variance. It is highly likely that the case-to-case differences are masking the subtle diurnal signal.

This project is ongoing.

Publications

Mechem, D. B., Y. L. Kogan, M. E. Childers, and K. M. Donner, 2005: Toward a diurnal climatology of cold-season turbulence statistics in continental stratocumulus as observed by the Atmospheric Radiation Measurement millimeter-wavelength cloud radars. Proc., *15th Atmospheric Radiation Measurement (ARM) Science Team Meeting*, Daytona Beach, FL., U.S. Dept. of Energy.



MMCR imagery from 0000-0600 UTC 29 March 2001. (a) Unprocessed reflectivity, plotted as a function of time and geometric height. (b) Unprocessed Doppler velocity in the geometric height coordinate. (c) Processed Doppler velocity in the transformed coordinate. A non-dimensional height of 0 corresponds to the ARSCL identified cloud base; 1 corresponds to cloud top. The processing procedure is described in detail in Section 2. (d) Time series of vertical velocity at three levels (non-dimensional heights of 0.25, 0.5, 0.75) in the cloud from 0200-0300 UTC. (e) Vertical velocity variance. (f) Skewness.

The Statistical Formulations of Cloud Parameters over the U.S. Southern Great Plains

Z. Kogan (primary – CIMMS at OU), Botnick, **Y. Kogan, Mechem**

NOAA Strategic Goal 2 *(Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond)*

Funding Agency: U.S. DOE

Objectives

Develop a parameterization of cloud variability for use in climate and numerical weather prediction models.

Accomplishments

This study focuses on two aspects of continental stratocumulus characterization: 1) determination of reflectivity threshold for discrimination between precipitating and non-precipitating Sc, and 2) description of Sc variability in both the horizontal and vertical directions.

Use of reflectivity threshold for separating precipitating and non-precipitating cloud is a common practice in analysis and microphysical retrieval of both marine and continental cloud systems. Studies in marine and continental clouds demonstrate the presence of a sharp, drizzle induced increase in reflectivity over the range from -20 to -15 dBZ, which strongly suggests the existence of a reflectivity threshold that separates drizzling and non-drizzling clouds. We verified this conclusion for winter continental stratiform clouds by analyzing a data collected over the SGP ACRF site from 1998 to 2003. The results show that the -17dBZ threshold in 96% of all cases defines the precipitating clouds. It is interesting to note that in this case the height of Zmax lies in the lower half of the cloud, while for non-precipitating clouds Zmax predominantly is located in the upper half of the cloud. This fact is consistent with the established notion that Z is increasing with height in non-precipitating, while decreasing in precipitating Sc.

Numerous studies have shown that neglecting variability at scales smaller than model grid (subgrid variability) can lead to substantial biases in radiative quantities, as well as microphysical process rates. Variability is commonly characterized by a PDF, however, it is unknown if variability has a significant vertical dependence. If the latter can be neglected, then a universal PDF with a constant standard deviation could be employed to characterize variability in the whole cloud layer. As part of the REU program, Aaron Botnick has conducted analysis of stratocumulus over ARM SGP ACRF site, which showed a strong vertical dependence of variability in these clouds. The layer near cloud top displayed the highest variability. This ranged from 2.4-4.0 dBZ, rising steadily as reflectivity was increased in the subcloud layer, following a change from non-drizzling to a drizzling state. The subcloud layer had the second highest variability, ranging from 1.8 dBZ to a local maximum of 2.7 dBZ at the drizzle threshold of -17 dBZ. The base and middle layers of the cloud showed similar trends to that of the subcloud layer. Non-drizzling segments had the smallest vertical variability; the vertical variability of drizzling segments was approximately 200% of non-drizzling segments. Results clearly showed that a vertically dependent subgrid cloud parameterization, both for drizzling and non-drizzling stratocumulus clouds, is needs to be implemented in mesoscale and global circulation models.

This project is ongoing.

Publications

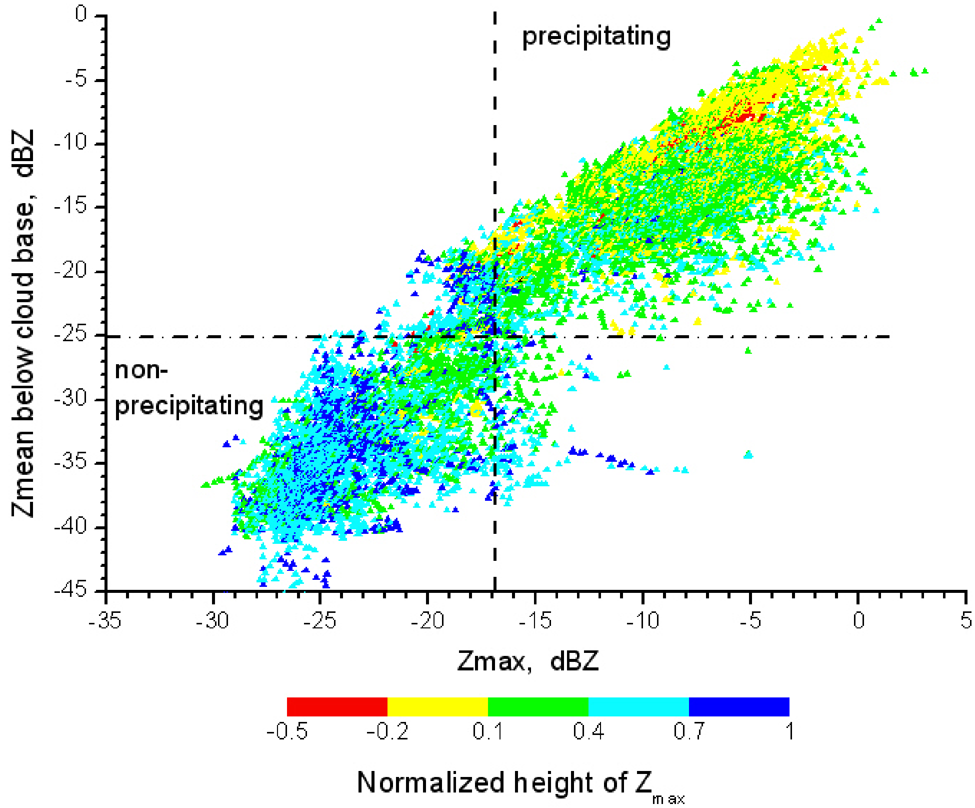
Kogan, Z.N., D. B. Mechem, and Y.L. Kogan, 2005: On parameterization of subgrid variability in stratiform clouds in large-scale models. *J. Geophys. Res.*, in press.

Kogan, Z.N., D. B. Mechem, and Y.L. Kogan, 2005: Analysis of Scale Dependence of Stratiform Clouds Variability based on Millimeter-wave Radar Data. Proc., *15th Atmospheric Radiation Measurement (ARM) Science Team Meeting*, Daytona Beach, FL, U.S. Dept. of Energy.

Mechem, D. B., and Y.L. Kogan, 2005: Representing Cloud Processing of Aerosol in Numerical Models. Proc., *15th Atmospheric Radiation Measurement (ARM) Science Team Meeting*, Daytona Beach, FL, U.S. Dept. of Energy.

Mechem, D.B., Y.L. Kogan, M.E. Childers, and K.M. Donner, 2005: Toward a Diurnal Climatology of Cold-Season Turbulence Statistics in Continental Stratocumulus as Observed by the Atmospheric Radiation Measurement Millimeter-Wavelength Cloud Radars. Proc., *15th Atmospheric Radiation Measurement (ARM) Science Team Meeting*, Daytona Beach, FL, U.S. Dept. of Energy.

Kogan, Z.N., D. B. Mechem, Y.L. Kogan, 2004: On characterization of sub-grid variability in stratiform clouds based on MMCR data. Proc., *14th International Conf. on Clouds and Precipitation*, Bologna, Italy, International Commission on Clouds and Precipitation.



Scatter plot of mean reflectivity below cloud base as a function of maximum reflectivity in the cloud. Symbols are color mapped by the normalized height of Zmax. The -17dBZ Zmax threshold discriminates well between cloud segments with Zmax located in the upper and lower half of the cloud.

Parameterization of Cloud Microphysics and Radiation

Y. Kogan (CIMMS at OU)

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: ONR

Objectives

Understand feedbacks between cloud microphysical, radiative and dynamical processes, and develop cloud and radiation parameterizations for use in numerical weather prediction models.

Accomplishments

Study continued of turbulence mixing effects on formation of cloud microstructure and production of drizzle in boundary layer stratocumulus by conducting a new set of simulations with enhanced spatial resolution (up to 10 m in the vertical). The analysis of the ensemble of close to 120,000 trajectories confirmed the findings of the low resolution study, namely that in drizzling stratocumulus air parcels repeatedly cycle in the cloud for long periods of time and that in-cloud time-scales are insignificantly affected by the high frequency turbulence fluctuations. Long in-cloud residence times combined with the induced by turbulence spatial inhomogeneity of timescales leads to non-adiabatic mixing between “old” and “new” parcels. Our experiments demonstrated that mixing of parcels with different histories, i.e., with drop size distributions at different stages of their evolution, provides embryos for coagulation in new parcels, contributes to drop spectral broadening and accelerates drizzle formation.

Our results also suggest an interesting mechanism of transition from non-drizzling to drizzling stratocumulus cloud. Mild evaporation of drops below cloud base in the initially non-drizzling cloud will lead early on to weak destabilization of the subcloud layer which, in turn, will result in the increase in the number of air parcels confined to the cloud layer. These parcels with long timescale trajectories will favor enhanced drizzle growth, which, in turn, will lead to stronger evaporation below cloud base followed by a stronger increase in stability of the subcloud layer and decoupling, all resulting in more air parcel cycling in cloud and more drizzle. The described positive feedback mechanism may eventually lead to stratocumulus cloud breakup.

This project is ongoing.

Publications

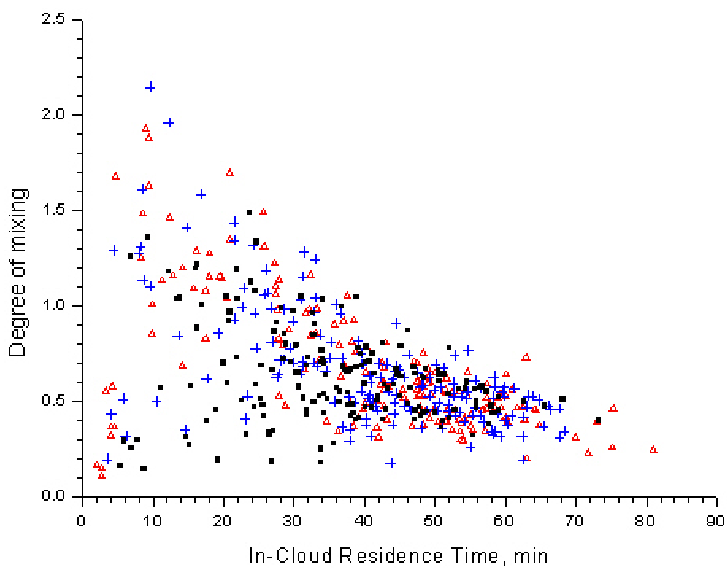
Kogan, Y.L., 2005: Large eddy simulation of air parcels in stratocumulus clouds: timescales and spatial variability. *J. Atmos. Sci.*, in press.

Kogan, Y.L., 2005: On Parameterization of Drizzle and Cloud Microphysics. *5th International Scientific Conference on the Global Energy and Water Cycle*, Orange County, CA

Kogan, Y.L., 2004: Air recycling in boundary layer clouds and its effect on cloud microstructure. Preprints, *16th Symposium on Boundary Layers and Turbulence*. Portland, ME., Amer. Meteor. Soc.

Kogan, Y.L., 2004: On the role of large-scale turbulence in cloud microstructure formation. Proc., *14th Inter. Conf. on Clouds and Precipitation*, Bologna, Italy, International Commission on Clouds and Precipitation.

Yang, B., and Y. L. Kogan, 2004: On heterogeneity of drizzle in a stratocumulus-topped boundary layer. Proc., *14th Inter. Conf. on Clouds and Precipitation*, Bologna, Italy, International Commission on Clouds and Precipitation.



The degree of mixing (the ratio of standard deviation of the residence time in an air volume to its mean value) shown at three cloud levels (bottom-triangles, middle- pluses, squares-top). The highest degree of mixing is for ‘new’ parcels with small residence times.

Mesoscale Dynamics

Xu (primary – NSSL), Lei, Gao, NSSL scientists, Institute of Atmospheric Physics (IAP – Beijing)

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: NSF

Objectives

Explore various instability mechanisms that will provide possible explanations for initiations of some observed mesoscale rainbands and severe storm elements embedded in frontal rainbands. These include, but not limited to, studies of modal and non-modal growths and structures in the presence of symmetric stability and instability.

Accomplishments

The classic normal modes for symmetric perturbations in a layer of vertically sheared basic flow are re-examined and classified into three types: paired growing and decaying modes, paired slowly propagating modes, and paired fast propagating modes. For a growing (or decaying mode), the cross-band vertical circulation is tilted between the M-surface and B-surface, so the growth (or decay) of the mode is caused by the positive (negative) feedback of the inertial and buoyancy perturbation forces to the cross-band motions. For a slowly propagating mode, the cross-band circulation is tilted more slantwise than the M-surface and B-surface, so the mode propagation is driven by the inertial restoring force in the forward direction but retarded by the buoyancy restoring force in the backward direction. For a fast propagating mode, the cross-band circulation is tilted in the opposite direction with respect to the M-surface and B-surface, so the mode propagation is driven by the inertial and buoyancy restoring forces both in the forward direction. The cross-band velocity component modes are shown to be orthogonal between different pairs, but the full-component modes are non-orthogonal (measured by the inner-product associated with the perturbation energy). Within each pair, the two modes have the same pattern in each component field but opposite polarization relationships between the cross-band velocity and the remaining component fields. Thus, large non-modal energy growths can be produced by paired normal modes.

This project is ongoing.

Publications

Xu, Q., W. Gu, and S. Gao, 2005: Nonlinear oscillations of semigeostrophic Eady waves in the presence of diffusivity. *Adv. Atmos. Sci.*, **22**, 49-57.

Xu, Q., 2004: Nearly symmetric and nearly baroclinic instabilities in the presence of diffusivity. Part II: Mode structures and energetics. *J. Fluid Mech.*, **500**, 283-312.

Xu, Q., 2005: Non-modal growths of symmetric perturbations produced by paired normal modes. CD-ROM, *32nd Conf. on Radar Meteorology*, Albuquerque, NM, Amer. Meteor. Soc., paper 6M4.

Doppler Radar Data Quality Control, Analyses and Assimilation

Xu (primary – NSSL), **P. Zhang**, **Nai**, **Wei**, **Liu**, Lu, **Wang**, NSSL scientists, NRL, IAP, Lanzhou University

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: ONR and CIMMS Task II

Objectives

Advance knowledge and skills in storm-scale data assimilation; develop state-of-art technologies and software for real-time applications of remotely sensed high-resolution measurements, especially those from Doppler radars, to improve numerical nowcasts and forecasts of severe storms and hazard weather conditions.

Accomplishments

Doppler radar data quality control. Based on the Bayesian statistical decision theory, a probabilistic QC technique is developed to identify and flag migrating-bird contaminated sweeps of level II velocity scans at the lowest elevation angle using three identified QC parameters. The QC technique can use either each single QC parameter or all the three in combination. The single-parameter QC technique is shown to be useful for evaluating the effectiveness of each QC parameter based on the smallness of the tested percentages of wrong decision by using the ground truth information (if available) or based on the smallness of the estimated probabilities of wrong decision (if there is no ground truth information). The multi-parameter QC technique is demonstrated to be much better than any of the three single-parameter QC techniques, as indicated by the very small value of the tested percentages of wrong decision for no-flag decisions (not contaminated by migrating birds). Since the averages of the estimated probabilities of wrong decision are quite close to the tested percentages of wrong decision, they can provide useful information about the probability of wrong decision when the multi-parameter QC technique is used for real applications (with no ground truth information).

Storm targeted radar wind retrieval system. In collaboration with scientists at NSSL, a storm targeted radar wind retrieval (STWR) system was developed. This system was tested at the Oklahoma Norman Weather Forecast Office to provide additional information for tornado warning in 2004 spring season. Since then, the system has been further upgraded with two new functions: (i) an easy-to-use interface that can control the data selection and retrieval processes, and (ii) vector wind display overlaid with the radar reflectivity (or radial-wind) image on detailed county maps. These functions are designed to target and track critical areas threatened by the storm, to display detailed storm winds in the targeted areas and thus to help the forecasters to make warning decisions with an improved accuracy. Built on the achievements of WDSS II and on the success of Collaborative Radar Acquisition Field Test (CRAFT) project, our research algorithms were converted to an operation-oriented application system. The STWR functions and features can be summarized as follow: 1) real-time level II data display; 2) automatic estimate of moving speed and direction of user-selected feature; 3) user-friendly interface; 4) dynamic feature following wind retrieval; 5) automatic and interactive display of retrieved wind field. The accomplishment of STWR system also provides a prototype framework for converting other algorithms written in different programming language rather than C++ to a real-time operation-oriented application through WDSS II system in the future.

Phased array radar data quality control and assimilation. An initial effort has been made in assimilating phased array radar data and the goal is to improve numerical analyses and predictions of severe storms. To achieve this goal, a comprehensive approach is being taken to attack problems in three important aspects: (i) phased array radar data quality control to meet the high-quality standard required by data assimilation, (ii) estimation of phased array radar radial-velocity observation error variance and background wind error covariance, and (iii) phased array radar data assimilation using the estimated error statistics. This approach is demonstrated by applying the upgraded 3.5-dimensional variational (3.5dVar) radar data assimilation package to phased array radar data collected for the squall line on 2 June 2004. The results show that using the COAMPS background can simplify the three-step dealiasing. With the fast phased array radar scans, radial-velocity innovation data can be accumulated rapidly, so the unknown radar radial-velocity observation error variance and background wind error covariance can be estimated nearly real-time by using the statistical method and thinning strategy developed in this paper. The estimated error variance and covariance can be used by the 3.5dVar (upgraded in this paper) with the COAMPS to improve the numerical analyses and predictions of the squall line (see figures below).

These projects are ongoing.

Publications

Liu, S., Q. Xu, and P. Zhang, 2005: Quality control of Doppler velocities contaminated by migrating birds. Part II: Bayes identification and probability tests. *J. Atmos. Oceanic Technol.* **22**, 1114-1121.

Liu, S., C. Qiu, Q. Xu, P. Zhang, and J. Gao, and A. Shao, 2005: An improved method for Doppler wind and thermodynamic retrievals. *Adv. Atmos. Sci.*, **22**, 90-102.

Liu, S., C. Qiu, Q. Xu, and P. Zhang, 2004: An improved time interpolation for three-dimensional Doppler wind analysis. *J. Appl. Meteor.* **43**, 1379-1391.

Qiu, C., A. Shao, S. Liu, and Q. Xu,, 2005: A two-step variational method for three-dimensional wind retrieval from single Doppler radar. *Meteorol. Atmos. Phys.*, DOI: 10.1007/s00703-004-0093-8.

Zhang, S.W., C. J. Qiu, and Q. Xu, 2005: Reply. *J. Appl. Meteor.*, **44**, 551-552.

Gao, J., K. K. Droegemeier, J. Gong, and Q. Xu, 2004: A method for retrieving mean horizontal wind profiles from single Doppler radar observations contaminated by aliasing. *Mon. Wea. Rev.*, **132**, 1399-1409.

Xu, Q., 2005: Representations of inverse covariances by differential operators. *Adv. Atmos. Sci.*, **22**, 181-198.

Zhang, P., S. Liu, and Q. Xu, 2005: Quality control of Doppler velocities contaminated by migrating birds. Part I: Feature extraction and quality control parameters. *J. Atmos. Oceanic Technol.*, **22**, 1105-1113.

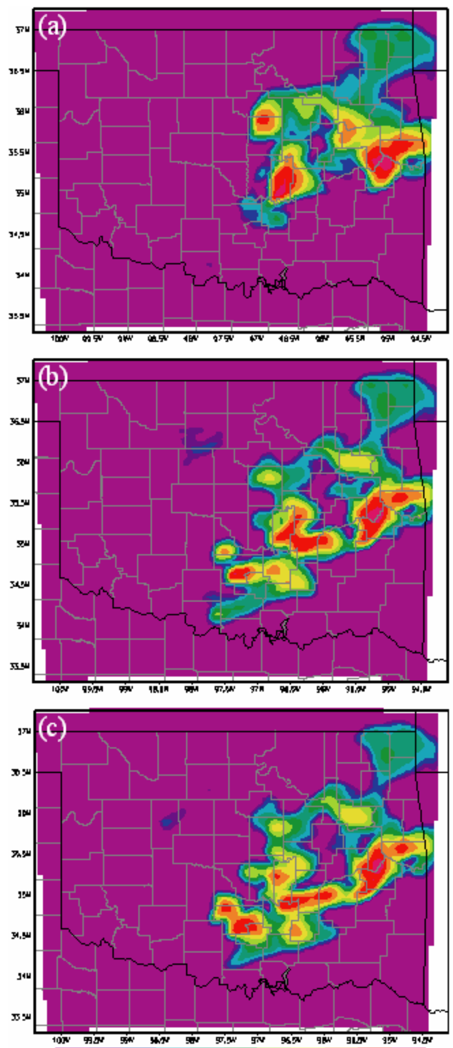
Harasti, P. R., D. Smalley, M. Weber, C. Kessinger, Q. Xu, P. Zhang, S. Liu, T. Tsui, J. Cook, and Q. Zhao, 2005: On the development of a multi-algorithm radar data quality control system at the naval research laboratory. CD-ROM, *32nd Conf. on Radar Meteorology*, Albuquerque, NM, Amer. Meteor. Soc.

Zhang, P., S. Liu, Q. Xu, L. Song, 2005: Storm targeted radar wind retrieval system. CD-ROM, *32nd Conf. on Radar Meteorology*, Albuquerque, NM, Amer. Meteor. Soc., P8R1.

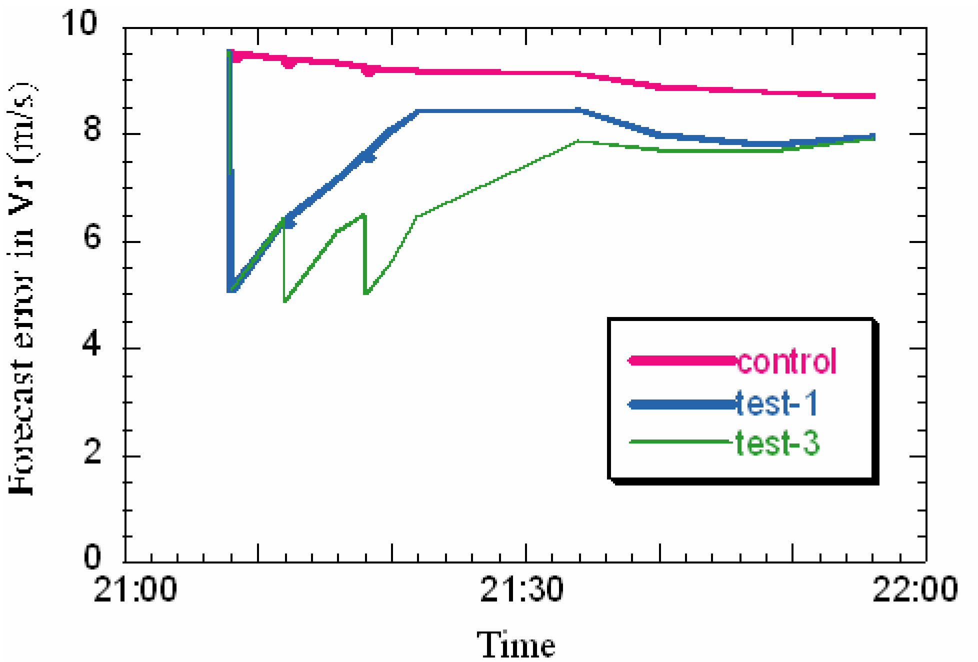
Zhao, Q., J. Cook, Q. Xu, and P. Harasti, 2005: Improving very-short-term storm predictions by assimilating radar data into a mesoscale NWP model. CD-ROM, *32nd Conf. on Radar Meteorology*, Albuquerque, NM, Amer. Meteor. Soc.

Xu, Q., K. Nai, L. Wei, P. Zhang, L. Wang, and H. Lu, Q. Zhao, 2005: Progress in Doppler radar data assimilation. CD-ROM, *32nd Conf. on Radar Meteorology*, Albuquerque, NM, Amer. Meteor. Soc., JP1J7.

Xu, Q., 2005: Non-modal growths of symmetric perturbations produced by paired normal modes. CD-ROM, *32nd Conf. on Radar Meteorology*, Albuquerque, NM, Amer. Meteor. Soc., 6M4.



Reflectivity fields at z = 3 km and 2200 UTC on 2 June 2004 predicted by (a) the control run without using radar data, (b) the test-1 run with three phased array radar volume scans assimilated through one cycle from 2108- 2112 UTC, (c) the test-3 run with nine phased array radar volume scans assimilated through three cycles from 2108-2120 UTC.



The rms differences between the model-produced and observed radial-velocity fields (averaged in the observation space). The red, blue and green curves are for the results obtained from the control run, test-1 run and test-3 run, respectively.

Numerical Modeling Study of the Time-Dependent Behavior of Convection
Doswell (primary – CIMMS at OU), Weber, **Loftus, Baranowski**

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: NSF

Objectives
Determine how environmental factors, notably the forcing that initiates deep convection and the environmental wind and thermodynamic profiles, control the time-dependent behavior of deep convective storms.

Accomplishments
This work involves the use of a 3-d cloud model ARPI3 (similar to the ARPS model), developed by Daniel Weber (CAPS). The goal is to determine how environmental factors, notably the forcing that initiates deep convection and the environmental wind and thermodynamic profiles, control the time-dependent behavior of deep convective storms. Early simulation study results can be viewed at http://www.caps.ou.edu/~dweber/bubbles.html. An algorithm for parameterized momentum forcing has been developed, forming the basis for the M.S. thesis successfully defended in spring 2005 by Adrian Loftus. This work is in the process of being prepared for formal submission to *Monthly Weather Review*. Work by graduate student Benjamin Baranowski is underway to complete a study of the effects of resolution on the simulations and to develop scripts for the parameter sensitivity studies.

This project is ongoing.

Hodograph-Based Supercell Storm Motion Estimates

Doswell (primary – CIMMS at OU)**, Ramsay**

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: CIMMS

Objectives

Investigate the use of observed hodographs to predict supercell motion.

Accomplishments

Four supercell motion forecast algorithms were investigated with respect to their hodograph analysis parameters. Another method derived from the data presented herein, the so-called "Offset" method, was used to develop a baseline standard for the aforementioned schemes, using the observed storm motions and the mean wind. It is not a forecast scheme as it is based on knowing the observed storm motions. This work explored the sensitivity of these algorithms to their arbitrary parameters by systematically varying those parameters, using a dataset of 394 right-moving supercells, and associated proximity soundings. The parameters used in these algorithms to define the layer depths for advection and/or propagation of supercells, have not been shown to be optimum for this purpose. These arbitrary parameters comprise the top and bottom levels of the mean wind layer, and a deviation vector from the mean wind defined through that layer. Two of the most recently developed algorithms have also implemented the vertical wind shear vector over an arbitrary layer depth. It has been found that, among other results, the scheme using both mean wind and vertical wind shear is more sensitive to the depth of mean wind layer than it is to the depth of the vertical wind shear layer. It also has been shown that, when using the simplest schemes, the most accurate forecasts, on average, are obtained by using deep mean wind layers (i.e., greater than 0-10 km). Indeed, all the forecast schemes show a strong tendency for the u-component of the predicted storm motion to be regulated by the depth of the mean wind layer. The v-component of the prediction storm motion, on the other hand, appears to be controlled by the deviation vector from the layer-mean wind. Although the schemes using vertical shear are shown to perform somewhat better on the average than schemes based on the mean wind alone, there are times in which they also result in large forecast errors. The results demonstrate the inherent difficulty in using an observed hodograph to predict supercell motion.

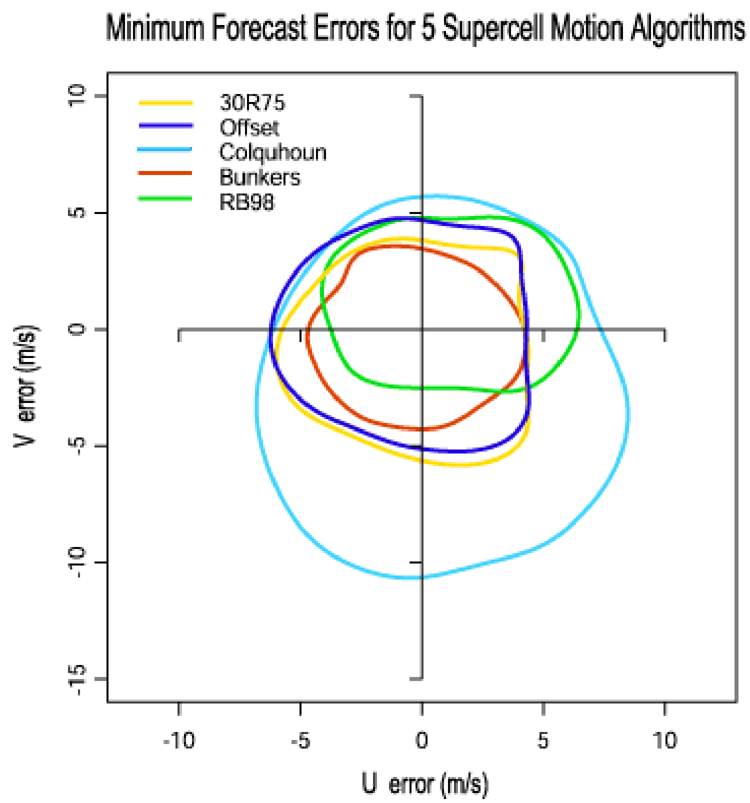
This project has been completed.

Publications

Ramsay, H., and C. A. Doswell III, 2004: Exploring hodograph-based techniques to estimate the velocity of right-moving supercells. CD-ROM, *22nd Conf. Severe Local Storms,* Hyannis, MA, Amer. Meteor. Soc.

Ramsay, H., and C.A. Doswell III: 2006: A sensitivity study of hodograph-based methods for estimating supercell motion. *Wea. Forecasting***, 21**, in press.

Trapp, R.J., C.A. Doswell III, and M. Huber, 2004: Do supercells play a role in the equilibration of the large-scale atmosphere? CD-ROM, *22nd Conf. Severe Local Storms,* Hyannis, MA, Amer. Meteor. Soc.



From Ramsay and Doswell (2006; Fig. 12) – KDE plot showing the distribution of forecast vector errors for each 'optimum' scheme, as described in the paper. The Offset method is shown for comparison.

Vertical Vortices in the Convective Boundary Layer

Kanak (primary – CIMMS at OU), **Lilly**, **Snow**

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: NSF

Objectives

Identify the dynamical mechanisms of vertical vortex formation in the convective boundary layer and assess the role of these vertical vortices on boundary layer processes.

Accomplishments

Quiescent environments. Three-dimensional, two-meter resolution boundary layer LESs have been conducted, the results of which exhibit vertical vortices with dust devil-scale motions. This is likely the first LES to resolve and simulate vertical vortices with dust devil characteristics. The vortices' structure and intensity are compared to those of dust devil field observations by Sinclair and others. The latest results (2 m and 4 m resolution simulations) show that vertical vortices often form in a bookend vortex pattern with pairs of counter-rotating vortices. This structure implies that asymmetries in the convective cell pattern may be responsible for local horizontal jets, which are associated with local horizontal wind shears. These may be a source of vertical vorticity for the dust devil-like vortices. It also appears that many vortices have quite asymmetric structure, with much stronger winds on one side of the vortex than the other. Similarly, the maximum updraft and minimum pressure centers are often offset from the center of the circulations. Preliminary analysis of terms of the vertical vorticity budget suggest that tilting terms are significant on one side of the vortex (where the wind speeds are greatest), and the stretching terms are relatively small in association with established vortices. A vortex detection algorithm has been completed and is being applied to the data to quantify the existence and physical characteristics of the simulated vortices. The algorithm is based on the procedure described by McWilliams et al. (1999).

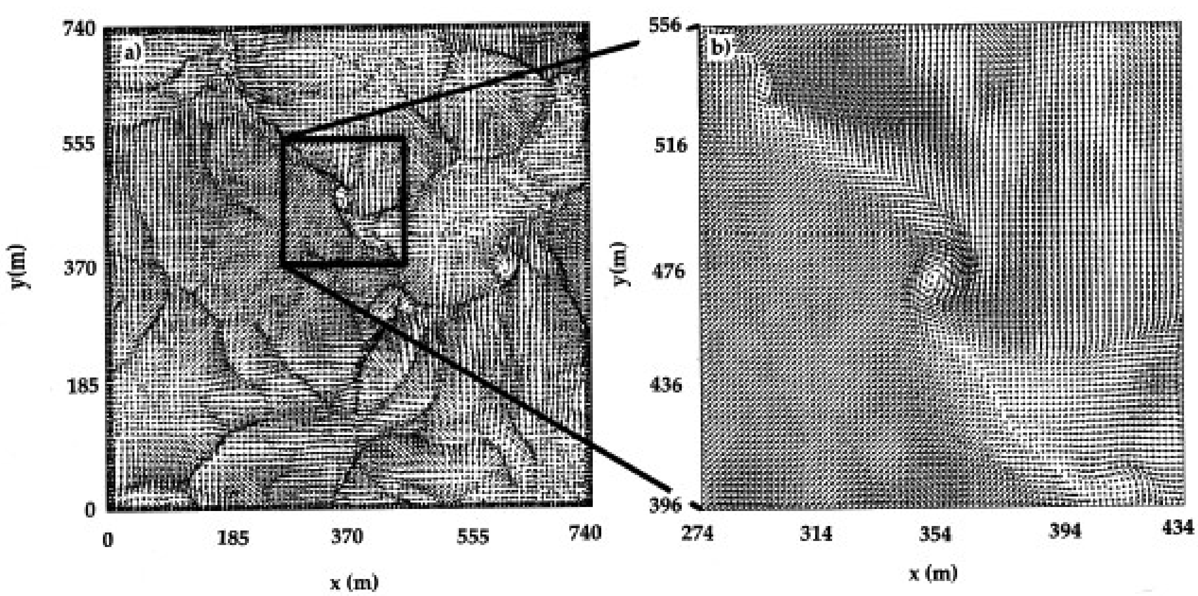
<u>Environments with ambient wind shears</u>. Wu et al. (1992) showed that in numerical simulations of Rayleigh-Benard convection, the turbulent perturbations had high helicity values when a mean wind that turns with height (helical hodograph) is imposed. To examine whether this is true for vertical vortices only (rather than the combination of vertical and horizontally helical perturbation flows) a new study has been designed. Two new experiments have been completed using 6 m horizontal grid spacing. These preliminary results imply that the presence of environmental wind appears to inhibit the formation of vertical vortices as compared with the case of a quiescent environment. The first simulation includes the case of a linear mean wind shear, the second a circular hodograph (shear vector turning with height). The newly completed vortex detection algorithm will be used to quantify the effects of the various shear profiles on the number of vortices and their physical characteristics. In addition, other simulations are planned to expand the parameter space to include more shear profiles.

<u>Environments including water vapor</u>. A simulation has been completed that includes the simulation of water vapor in the convective boundary layer without mean winds. It is planned to compare the results to the dry simulations and attempt to make comparisons with observations from the recent IHOP field program.

This project is ongoing.

Publications

Kanak, K. M. 2005: Numerical simulation of dust devil - scale vortices. *Quart. J. Roy. Meteor. Soc.*, **131**, 1271-1292.



XY cross-sections at   = 2.1 m of horizontal velocity vectors at t = 1000 s. (a) horizontal velocity vectors plotted at every fourth grid point in the total simulation domain 740 m x 740 m (370 x 370 grid points). Maximum velocity vector length is equal to 7.9 m s-1; (b) Expanded section of Fig. 1a of size 160 m x 160 m (80 x 80 grid points) in which a vector is plotted at every grid point. A black box on Fig. 1a denotes the vortex of interest that is expanded in Fig. 1b. Maximum velocity vector length is equal to 6.2 m s-1.

Martian Dust Devils

Kanak (primary – CIMMS at OU), Cantor, Edgett

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: NSF and CIMMS Task I

Objectives

Analyze Martian dust devil characteristics as determined by Mars Orbiter Camera (MOC) images and make comparisons with terrestrial dust devils; gain insight into dust devil formation and maintenance dynamics, and their role in boundary layer processes, by comparison of their characteristics in two different atmospheres.

Accomplishments

Collaborative efforts with Dr. Ken Edgett and Dr. Bruce Cantor at Malin Space Science Systems (MSSS) have resulted in a draft paper on Martian dust devils to be submitted to Journal of Geophysical Research. In this paper, observations of dust devils and dust devil tracks from Mars Orbiter Camera images are described. Recent data from the Mars Rover Thermal Emission Spectrometer is used to determine a representative temperature profile that might be typical of Martian dust devil environments in order to make estimates of tangential wind speeds given the physical dimensions determined from the MOC images. The ubiquitous dust devil tracks that mark the Martian surface are shown below.

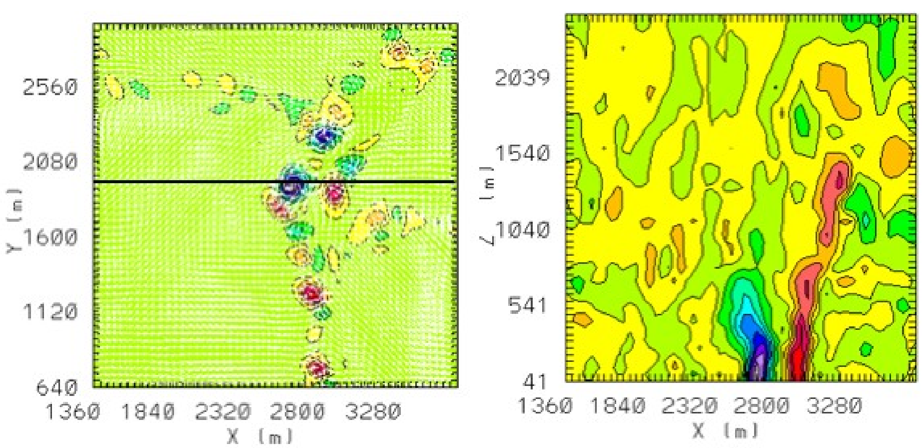
In addition, a LES of the Martian boundary layer has been conducted and the results were presented at the 2005 36th Lunar and Planetary Sciences meeting. Next, the vortex detection algorithm will be again used to quantify the simulated vortices and the results compared to the observations given in Fisher et al. (2005). A paper by K. Kanak is planned for these results for submission to *Journal of Geophysical Research – Planets*.

This project is ongoing.

Publications

Kanak, K. M., 2005: A Large Eddy Simulation of coherent structures and embedded dust devil-like vortices in the Martian atmospheric boundary layer. *36th Lunar and Planetary Sciences Conf.*, Houston, TX. Lunar and Planetary Institute and NASA, 2158.

Cantor, B. A., K. M. Kanak, and K. E. Edgett, 2005: Planet-wide Survey of Martian Dust Devils and Tracks: MOC Observations from 1997-2005. *J. Geophys. Res.-Planets*, to be submitted.



From numerical simulation of Martian convective boundary layer: (a) Sub-domain of XY cross-section at t = 4580 s and z =21 m of vertical vorticity with wind vectors overlain. Max value (red) is 0.198 s-1, min value (gray) is -0.32 s-1, and the contour interval is 0.037 s-1. (b) Sub-domain XZ cross-section at t= 4580 s and Y = 1820 m of vertical vorticity. Cross-section is taken along the black line in (a). Max. value (red) is 0.18 s-1, min. value (grey) is -0.33 s-1 and the contour interval is 0.066 s-1. Zero values are denoted by yellow.

Idealized Convection in Shear

Silveira, Kanak (primary – CIMMS at OU), **Straka, Shapiro, Leslie**

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: NSF and CIMMS Task I

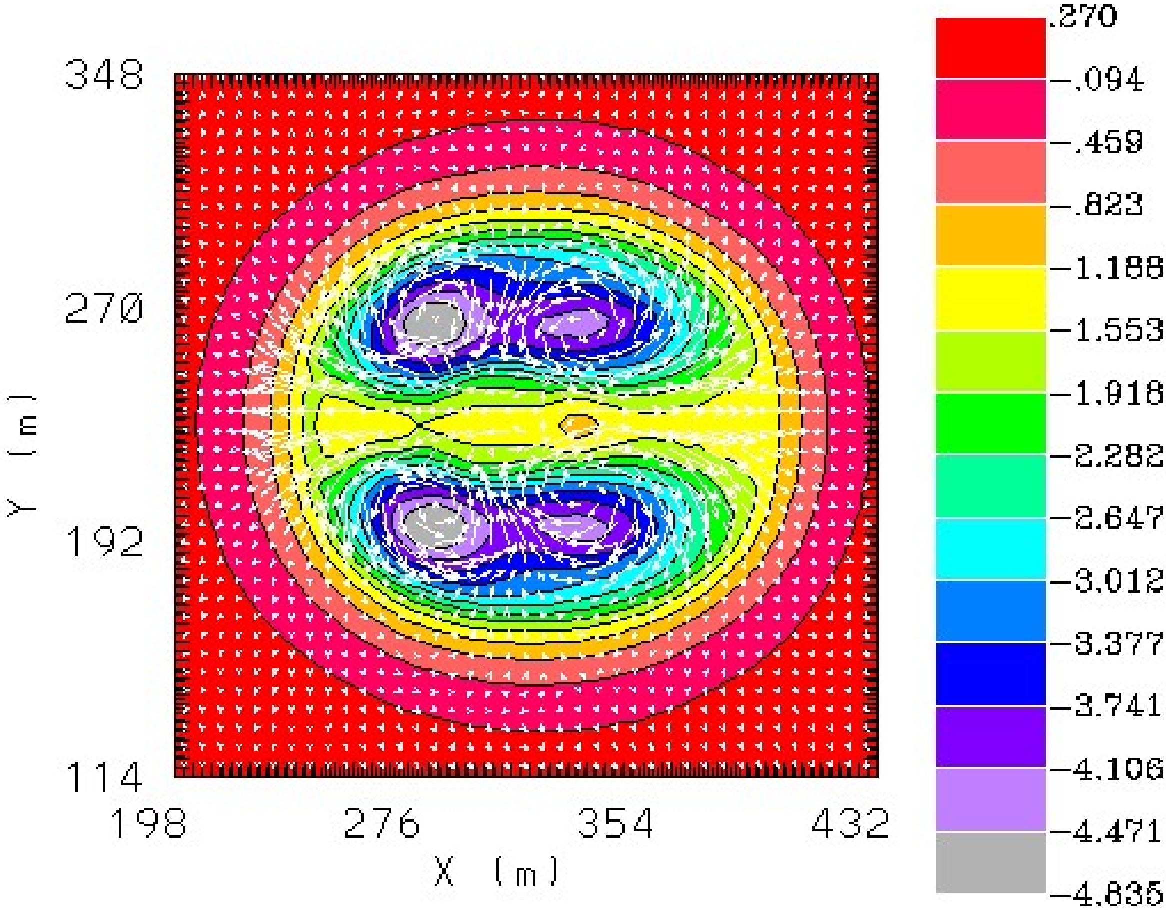
Objectives

Examine the formation of vertical vortices within idealized ellipsoidal convective elements in quiescent ambient flows, and explore the effects of ambient winds, on the formation of these vertical vortices.

Accomplishments

The work presented in Shapiro and Kanak (2002) has been extended to explore the effects of ambient wind on the formation of vertical vortices in ellipsoidal thermal elements. A suite of numerical simulations, with all factors held constant from the previously published results, except for the addition of ambient wind, has been completed. Partial analysis has been conducted and a new manuscript describing the results is anticipated. The figure below shows a representative sample of an XY cross-section that shows a quadrapole of vortices that form within the rising thermal and the associated pressure field.

This project is ongoing.



Horizontal cross-sections for horizontally elliptical thermal at t = 168 s and z = 418.5 m of white horizontal velocity vectors overlain on contours of perturbation pressure. Maximum vector length is 1.90 m s-1. Pressure contours values are given in Pa.

Evaluations of Microphysical Parameterizations

Straka (primary – OU School of Meteorology), **Kanak**, Gilmore, **Rasmussen**

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: CIMMS Task I

Objectives

Explore the consistency of certain microphysical parameterizations with the physical processes they are designed to represent.

Accomplishments

The equations which represent two microphysical processes, for which total number concentration Nt should be conserved, are integrated over sizes of hydrometeor diameters D for one- and two-moment methods. The gamma distribution function is assumed and incorporates total mixing ratio q, Nt, and mean diameter Dn, (inverse of the distribution slope l). In all the methods, the slope intercept, no, is diagnosed or specified but not predicted. The moment methods explored include:

- Scheme-A: the one-moment method where q is predicted, no is specified, and Nt and Dn are diagnosed;
- Scheme B: the one-moment method where q is predicted, Dn is specified, and Nt and no are diagnosed;
- Scheme E: the two-moment method where q and Dn are predicted, and Nt and no are diagnosed;
- Scheme F: the two-moment method where q and Nt are predicted, and no and Dn are diagnosed.

In order to more easily discern the strengths and weaknesses of each moment-method, two processes are considered: vapor diffusional growth and continuous collection growth, and in both cases there is no introduction of new particles (dNt/Dt = 0). It is demonstrated for the processes examined that all of the schemes fail to conserve Nt and have other unphysical attributes, except the two-moment method where q and Nt are predicted.

In a separate paper, it is demonstrated mathematically why Nt is not conserved when it should be conserved for continuous collection growth. The results for vapor diffusional growth are qualitatively similar. The figure below shows a time series of the total number concentration for each of the schemes A-F listed above. It is clear that only Scheme F conserves Nt for continuous collection growth. Scheme-B has the most erroneous solution with regard to the conservation of Nt.

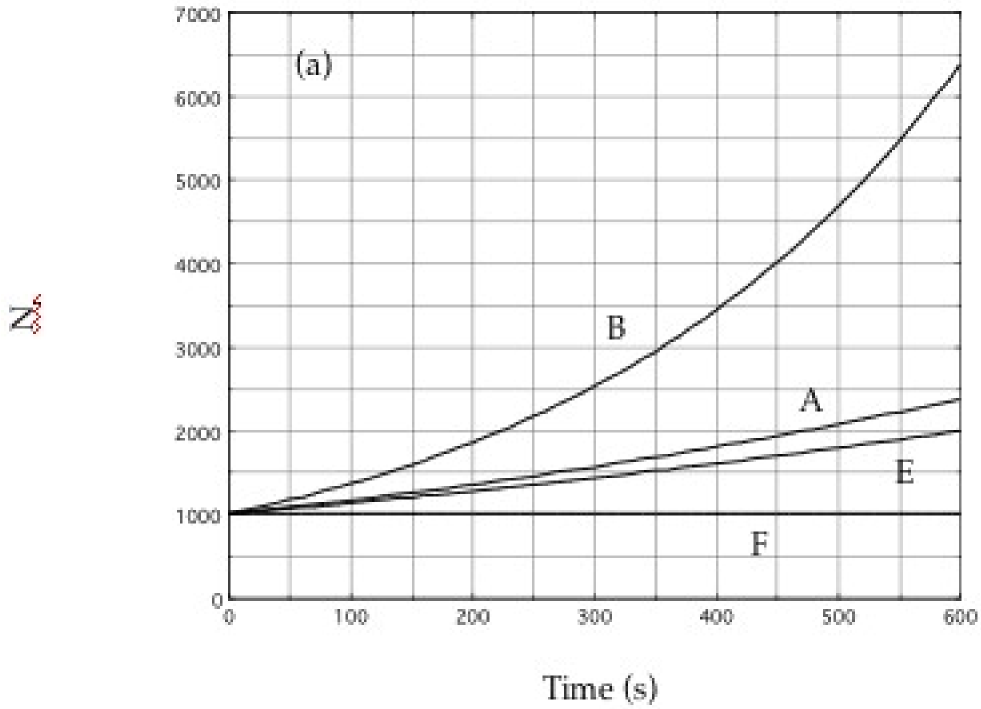
This project is ongoing.

Publications

Straka, J., M., K. M. Kanak, and M. S. Gilmore, 2005: The behavior of number concentration tendencies for conservative microphysical growth equations using bulk one-, and two-, moment schemes. *J. Applied Meteor.*, to be submitted.

Straka, J., M. S. Gilmore, K. M. Kanak and E. N. Rasmussen, 2005: A comparison of conservation properties of microphysical parameterizations: Part 1. Continuous Gamma distribution function with fixed shape parameter. *J. Applied Meteor.*, in press.

Straka, J. M., M. S. Gilmore, E. N. Rasmussen, and K. M. Kanak 2004: A comparison Of conservation properties of microphysical parameterizations: Continuous Gamma distribution function With fixed shape parameter. Preprints, *14th International Conference on Clouds and Precipitation*, July 19-23, Bologna, Italy, International Commission on Clouds and Precipitation.



Time series up to 600 sec. for schemes A-F of total number concentration, Nt, in units of per cubic meter.

Forecast Improvements

Warning Decision-Making Research and Training – *Advanced Warning Operations Course (AWOC)*

Decker, Hoggard, N. Levit, Magsig, Mohamad Said, Morris, Schlatter (primary – CIMMS at WDTB)**, Wood, Yu**

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: CIMMS Task II – WDTB

Objectives

Improve understanding of warning related issues, and help the NWS achieve GPRA goals 1-5 related to flash floods and tornadoes.

Accomplishments

CIMMS scientists were heavily integrated into the development, delivery, and support of WDTB's Advanced Warning Operations Course (AWOC). AWOC is a blended learning course designed to provide training on advanced warning decision making techniques to every NWS forecaster with warning responsibility (Meteorologists and Hydrologists). AWOC is a major NWS training initiative, and it represents a significant change in NWS training delivery. Instead of training the local trainer to deliver the majority of the training, a blend of distance learning technologies are utilized to deliver training directly to all forecasters. AWOC is the first initiative to deliver warning decision-making training to all forecasters since the WSR-88D Operations Course of the 1990s, at a significantly reduced cost. AWOC was developed in 2004 and delivered throughout 2005, and as of August 1, 2005 (see attached supporting figure) over 1300 forecasters have completed both components of AWOC (Core and Severe Tracks).

In collaboration with WDTB instructors, CIMMS scientists developed and delivered several recorded online training modules covering topics such as flash flood forecasting, hail forecasting, and storm reporting issues. CIMMS personnel also assisted WDTB instructors in developing numerous other online modules, live teletraining sessions, and an introductory motivational session featuring video of real warning operations and subject matter experts. The assistance included preparing graphics and animations, researching references, developing interactivity for the modules, and writing exams. CIMMS also contributed logistics support for AWOC and its management, including responses to questions from the field, assistance for local facilitators and provision of certificates of completions to students, and development of a semi-automated method of producing statistical progress reports of students and WFOs using NOAA's Learning Management System.

In addition to the online training modules, two significant components of CIMMS collaboration also include the Weather Event Simulator (WES) simulations and the AWOC facilitator workshop. CIMMS staff prepared and distributed simulation data and wrote the AWOC WES simulation guides for 4 severe weather events that were used to apply AWOC learning in an operational context. Six AWOC facilitator workshops, about four days each, were delivered to the training facilitator from each NWS Weather Forecast Office (WFO) or River Forecast Center from August through October of 2004. CIMMS staff built the WDTB Research and Training (WRAT) Lab to support the simulations component of AWOC facilitator training. The WRAT lab contains 25 triple-headed AWIPS workstations that mirrors the operational workstations used in warning operations. CIMMS personnel also gave several talks both in the WRAT lab and the classroom during the workshops, based on their subject matter expertise.

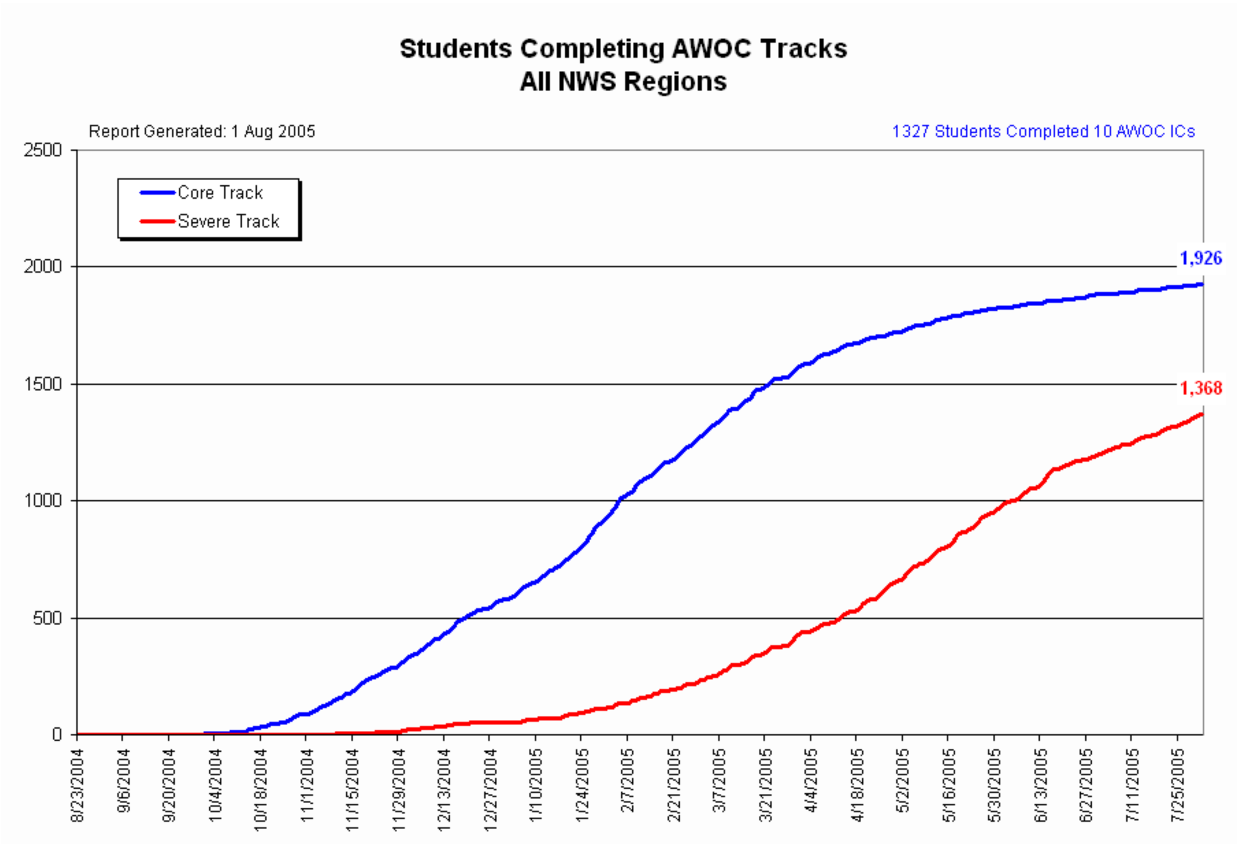
This project is ongoing.

Publications

WDTB AWOC official site: http://www.wdtb.noaa.gov/courses/awoc.

AIRMASS – Wichita http://www.wichita-amsnwa.org/index.php?display=conference

Ferree J.T., E.M. Quoetone, and M.A. Magsig, 2004: The Advanced Warning Operations Course. CD-ROM, *22nd Conf. on Severe Local Storms*, Hyannis, MA, Amer. Meteor. Soc.



AWOC completion statistics for all NWS personnel as of 1 Aug 2005. Blue (Red) line tracks the numbers of those that have completed the entire Core (Severe) Track.

Warning Decision-Making Research and Training – *AWIPS and WSR-88D Improvements*
Decker, Magsig, Schlatter (primary – CIMMS at WDTB)**, Wood**

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: CIMMS Task II – WDTB

Objectives
Improve understanding of warning related issues.

Accomplishments
The warning decision makers within each NWS office rely heavily on computing systems that need to run both quickly and efficiently, display data in an easy to view and navigate format, and have zero down time. With these goals in mind, CIMMS staff have aided in the training, testing, and development of two of the primary systems used in NWS warning operations: The Advanced Weather Information Processing System (AWIPS) and the Radar Product Generator (RPG) for the WSR-88D.

CIMMS staff working as subject matter experts with colleagues at WDTB has aided NOAA's NWS in many ways regarding the AWIPS program. In Operational Build Four (OB4) of AWIPS, CIMMS researchers were heavily involved in the design review, implementation, and training for the new Mesocyclone Detection Algorithm (MDA). The MDA is a significant upgrade to the NWS decision support system capabilities to better diagnose rotating thunderstorms and provide meaningful information for making warning decisions. See the publications for the link to the online AWIPS OB4 training, including the MDA recorded online training.

As part of the AWIPS software development process, beta versions may contain bugs or various performance issues which then could affect a forecaster's ability to make warning decisions. To help prevent these limitations from reaching the operational community, CIMMS researchers were invited to participate in thorough testing of the AWIPS software builds OB5 and OB6 well before it was released to the field. Their expertise in tracking down bugs or other performance-related problems was invaluable to the testing process. The testing also fed back into the development of the OB5 training. CIMMS assisted WDTB with putting together OB5 training on the new Terminal Doppler Weather Radar data, the new "Dig DMD" mesocyclone display, and the Flash Flood Monitoring and Prediction System. See the publications for the link to the online OB5 training.

In addition to AWIPS related training, another vital system in each NWS office is the RPG. CIMMS staff assisted WDTB in the development of training for ORPG Builds 6 and 7 by assessing the contents of each build, investigating the build integration and testing process, and providing prototype materials for training to WDTB instructors during Beta Testing. See publications for a link to the ORPG Build 7 training.

This project is ongoing.

Publications

Web guides:
http://www.wdtb.noaa.gov/buildTraining/AWIPS_OB4/index.html
http://www.wdtb.noaa.gov/buildTraining/TDWR/index.html
http://www.wdtb.noaa.gov/buildTraining/RPG7/index.html
http://www.wdtb.noaa.gov/buildTraining/RPG6/index.html

Warning Decision-Making Research and Training – *NOAA's NWS Weather Event Simulator*

Decker, Hoggard, Levit, Magsig (primary – CIMMS at WDTB)**, Mohammed Said, X. Yu, Mahoney,** Davis (FSL), Mandel (OST), Filiaggi (MDL)

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: CIMMS Task II – WDTB

Objectives

Develop simulation capabilities to enhance NWS warning decision making training and research; foster collaboration between NOAA and non-NOAA agencies using WES.

Accomplishments

Now in its fourth year since the initial release, NOAA's NWS Weather Event Simulator (WES) continues to play an expanding role in NWS training. Every NWS forecaster with warning responsibility is required by NWS Directive 20-101 to take two simulations using the WES for each significant weather season per year. The WES has also been a key part of the Warning Decision Training Branch's (WDTB) major new training initiative, the Advanced Warning Operations Course (AWOC). In AWOC, the WES was used by every student to apply AWOC learning in an operational context.

The WDTB is responsible for implementing the WES into NWS training, and CIMMS scientists support this initiative. Keeping WES up to date with the latest operational AWIPS tools and supporting the NWS WES program are two main areas in which CIMMS plays a prominent role. CIMMS scientists at the WDTB are the primary WES developers, and they create, test, distribute, and support WES for the NWS. CIMMS have also been proactive in releasing WES to non-NOAA collaborators and encouraging collaboration between NOAA and non-NOAA agencies.

In the past year, CIMMS scientists collaborated with the WDTB, the Forecast Systems Laboratory (FSL), the Meteorological Development Laboratory (MDL), and the Office of Science and Technology (OST) to develop and release two new versions of WES. WES3.3 and WES4.0 contained upgrades to support Operational Builds 3 and 4 of AWIPS, including new functionality such as the System for Convection Analysis and Nowcasting (SCAN), the Digital Mesocyclone product, the Mesocyclone Rapid Update product, and the Tornado Rapid Update product. The WES software was also improved to significantly reduce time spent preparing simulations and allow for easier management of external simulation inputs managed through the WES Scripting Language (WESSL). The improvements in WES have allowed for more operationally relevant simulations and training throughout the NWS.

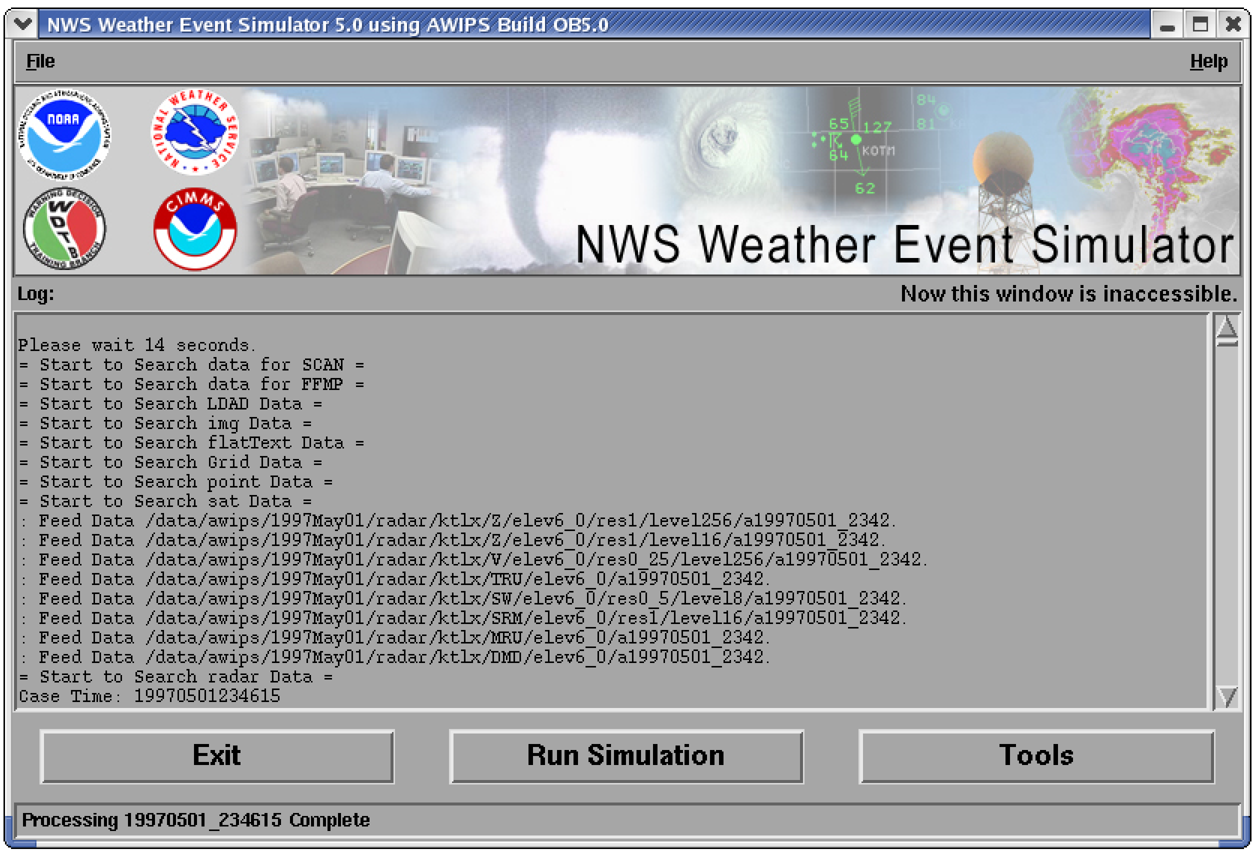
CIMMS also developed WES5.0 in the past year, though delivery occurred in the next CIMMS year. In WES5.0, CIMMS scientists upgraded WES to support Operational Build 5 of AWIPS, including new functionality such as the Terminal Doppler Weather Radar and the “Dig Digital Mesocyclone Detection” product. Additional improvements to the WES software included more realistic radar base data processing by utilizing fifteen second search intervals, and a new tool to allow for enhanced case review of static data sets.

This project is ongoing.

Publications

Magsig, M.A., N. A. Said, N. L. Levit, and X. Yu, 2004: The Weather Event Simulator and opportunities for the severe storms community. CD-ROM, *22nd Conf. on Severe Local Storms*, Hyannis, MA, Amer. Meteor. Soc.

Magsig, M. A., N. A. Said, N. L. Levit, and X. Yu, 2005: Build Four of NOAA’s NWS Weather Event Simulator, CD-ROM, *21st International Conf. on Interactive Information and Processing Systems (IIPS)*, January 2005, San Diego, CA, Amer. Meteor. Soc.



WES is the simulation and data playback capability for NOAA’s NWS and collaborative researchers. This interface is used to run simulations for training and research.

Warning Decision-Making Research and Training – *Distance Learning Operations Course (DLOC)*

Davis, Hoggard, N. Levit, Magsig, Mohamad Said, Schlatter, Wood (primary – CIMMS at WDTB)**, X. Yu,** NWS/WDTB collaborators

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: CIMMS Task II – WDTB

Objectives

Investigate warning decision making issues with NWS forecasters; evoke a better understanding of the warning decision making process; and transfer that knowledge to warning decision makers to improve performance.

Accomplishments

The WSR-88D Distance Learning Operations Course (DLOC) continues to be an area of active collaboration between CIMMS and the NWS Warning Decision Training Branch. DLOC teaches recently hired NWS meteorologists a wide range of topics regarding the WSR-88D and severe weather, including: radar theory, operations of the radar, AWIPS D2D functionality, radar data interpretation, storm interrogation techniques, and severe storm threat assessment and forecasting. In other words, DLOC is the integration of current meteorological and warning decision-making techniques with Doppler radar capabilities. This course is taught via a combination of teletraining, web-based instruction, on-station training, and residence training.

CIMMS staff has been closely involved with the development of DLOC. The collaborative work has included applied research on future radar improvements such as dual-polarization, as well as current WSR-88D capabilities to assess hail and flash flooding threats. As part of this training, CIMMS personnel work closely with radar engineers and software developers to determine how recent updates to different components of the WSR-88D and AWIPS impact the system as a whole. This work has allowed CIMMS staff to assist their WDTB collaborators in developing and updating significant portions of DLOC during the past year. Another area where CIMMS staff has played a critical role with DLOC is during the residence component of the course. The collaborative work with WDTB during these classes includes development and presentation of lecture materials, development and delivery of exercises and simulations (in the WDTB Research and Training laboratory), and providing expertise on warning-!
decision making issues to the class participants.

DLOC is significant because it is a critical piece in the development of new NWS forecasters for warning operations. All forecasters who may be responsible for issuing warnings for the NWS in the future are required to complete this training. Without the contributions of the CIMMS staff, DLOC would not have its current structure or effectiveness.

This project is ongoing.

Publications

Web Guides:

Radar Applications Using AWIPS: http://www.wdtb.noaa.gov/courses/dloc/topic1/Radar_Applications_Using_AWIPS.pdf
Introduction to the WSR-88D: http://www.wdtb.noaa.gov/courses/dloc/topic2/index.html
Convective Storm Structure and Evolution Student Guide: http://www.wdtb.noaa.gov/courses/dloc/topic7/topic7.pdf

Simulation from the WRAT Lab during a recent DLOC workshop.

Warning Decision-Making Research and Training – ***Winter Weather Track, Advanced Warning Operations Course (AWOC)***
Decker, Hoggard, Magsig, Mohamad Said, Morris, Schlatter, Schultz, Wood (primary – CIMMS at WDTB)**, X. Yu,** NWS/WDTB collaborators

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: CIMMS Task II – WDTB

Objectives
Investigate winter weather warning decision making issues with NWS forecasters and transfer that knowledge to new NWS forecasters to improve performance.

Accomplishments
Warning decision-making analysis is a significant area of active collaborative research between CIMMS and the NWS Warning Decision Training Branch. As winter weather warning performance is critical to the country, 2 of the 14 NWS Government Performance Review Act (GPRA) goals involve winter weather warning performance. In previous years, CIMMS and WDTB collaborated to deliver four winter weather, train-the-trainer workshops at the COMET facility in Boulder, CO. While a Level III follow-up evaluation of those workshops indicated that the training received by those NWS forecasters who attended the workshop positively impacted their job performance, the content was not effectively being transferred to others in their office. As a result of the effective, cost-efficient manner in which the Core and Severe Tracks of the Advanced Weather Operations Course (AWOC) were delivered to every forecaster in the NWS, a Winter Weather track was added to AWOC.

The Winter Weather Track utilizes Subject Matter Experts (SMEs) from across the country working in conjunction with CIMMS and NWS WDTB staff to develop over 15 hours of online training. The training content (currently under development with delivery planned in 2006) covers such topics as precipitation-type forecasting, climatology, forcing mechanisms, winter weather simulations, and user needs. While much of the work done to date has been preliminary, CIMMS staff has played a vital role in establishing course content, determining the learning and performance objectives, and establishing innovative ways to work collaboratively with other team members on their topics. As was the case in the original AWOC, the training will also entail students to complete an on-station simulation (via the WES) of a winter weather event as part of the course.

Using the Core and Severe Tracks of AWOC as an indicator, the Winter Weather Track of AWOC should likewise have a significant impact on NWS operations. The course is intended for every NWS forecaster who has responsibility for winter weather warning issuance. The course content would focus and enhance the expertise and skill sets of NWS forecasters in a similarly positive way as the original winter weather WDM workshops.

This project is ongoing.

Warning Decision-Making Research and Training – *Training on NOAA Management and Business Practices*

Morris (primary – CIMMS at WDTB)**,** NWS/WDTB collaborators

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: CIMMS Task II – WDTB

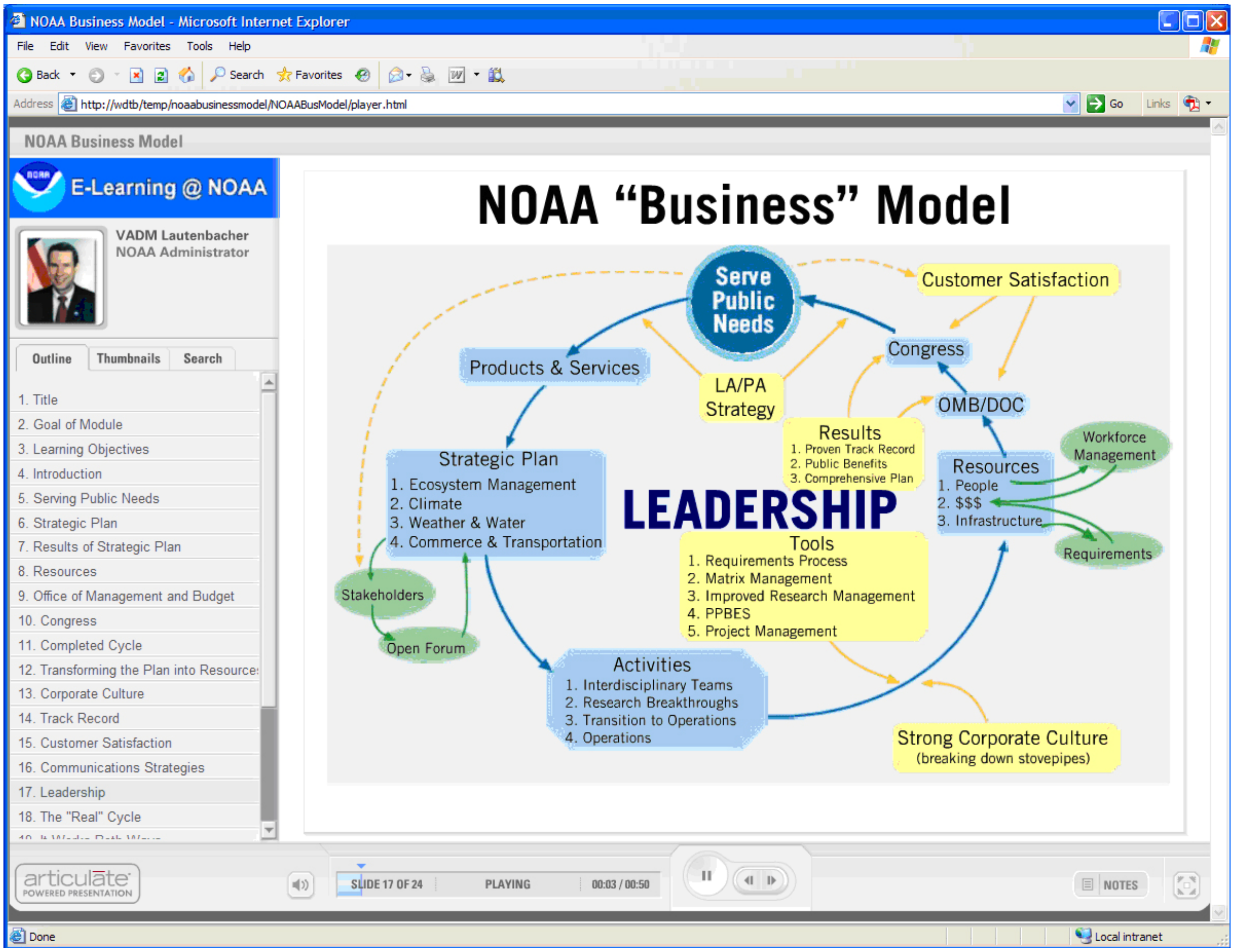
Objectives
Develop instructional material on NOAA management principles.

Accomplishments
During the past year, CIMMS staff was asked to use its expertise at developing distance learning materials to create web modules for NOAA management. These short modules were developed to deliver material about NOAA to individuals who were either not able to participate in the original presentation (i.e., NOAA Business Model) or are either new or potential NOAA employees (i.e., Team NOAA).

By transferring these materials to web modules, information was provided to a wider audience on NOAA's mission and strategic plan, as well as details about NOAA line offices and how NOAA provides benefits and services to its customers. The NOAA Business Model module utilizes audio from Vice Adm. Lautenbacher to introduce major issues in NOAA, including the PPBES system. Team NOAA was produced at the request of NOAA's Office of Education and Sustainable Development (OESD) and utilizes video resources from NOAA Public Affairs. These modules will be deployed using NOAA's Learning Management System.

This project has been completed.

Publications
NOAA Business Model: http://www.wdtb.noaa.gov/temp/noaabusinessmodel/



Example of user interface for the NOAA Business Model online module. Navigation through the module is facilitated by the menu at the left, and a slide narrated by Admiral Lautenbacher appears at the right. The slide illustrates NOAA's yearly budget cycle (blue) that links products and services to budgetary constraints by Congress and the Administration, NOAA's business practices and activities (yellow), and additional constraints (green).

Warning Decision-Making Research and Training – *WDTB Research and Training Lab*

Hoggard (primary – CIMMS at WDTB)**, N. Levit, Mohamad Said, X. Yu**

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: CIMMS Task II – WDTB

Objectives

Provide WDTB and CIMMS staff with a powerful and flexible computer lab to conduct facilitation workshops, residence training and weather research projects.

Accomplishments

An operationally representative environment has proven to be an important part of training and research in the warning decision making process. The WRAT lab provides instructors, NWS forecasters and CIMMS researchers with 25 AWIPS workstations that are identical to those found in NWS Weather Forecast Offices. The servers are configured to feed data to the workstations using a modified version of the Weather Event Simulator, as well as manage the lab efficiently and effectively. The systems have been configured to simplify the management of a large number of machines. Keeping all of the workstations identical allows the use of imaging technology. This allows the flexibility to change the entire lab overnight, rebuilding all of the workstations over the network from a previously built and tested image. Use of the secure shell agent allows us to build scripts on the server that can push a command to each of the workstations to perform the same task on all of the machines at once. The wake-on-lan feature allows the booting of all workstations with a single command from the server, and when combined with auto-login and special user-level video configuration files, the machines can boot all the way to a semi-kiosk mode, running a predefined set of applications, while managing access to the rest of the system.

CIMMS staff has developed the WRAT Lab Toolkit to help manage many of these system functions, as well as the training software and tools needed during residence training and facilitation workshops, including AWIPS, the Open System Radar Product Generation (ORPG), and the WDTB developed tools, including a customized lab version of the Weather Event Simulator (WES), the Weather Event Simulator Scripting Language (WESSL), and the Weather Case Browser.

Training is greatly enhanced by providing the NWS employees with an exact duplicate of the systems they will be working on when they return to their offices. Researchers also benefit from being able to view data in the same way as the forecasters, giving them a better understanding of the warning decision making process. This research is then used to improve training and, hence, forecasting.

This project is ongoing.

Publications

Levit, N. L., X. Yu, K. R. Hoggard and N. A. Said, 2004: Introducing the WRAT Lab. CD-ROM, *22nd Conf. on Severe Local Storms*, Hyannis, MA, Amer. Meteor. Soc.

Yu, X., N. L. Levit, K. R. Hoggard and N. A. Mohamad Said, 2005: Experiences towards Advanced Weather Research and Training. CD-ROM, *21st International Conf. on Interactive Information and Processing Systems (IIPS)*, San Diego, CA. Amer. Meteor. Soc.

The WDTB Research and Training (WRAT) Lab.

Warning Decision-Making Research and Training – *Training and Research Toolkit*

Hoggard, N. Levit, Mohamad Said, X. Yu (primary – CIMMS at WDTB), NWS/WDTB collaborators

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: CIMMS Task II – WDTB

Objectives

Provide an advanced, effective and flexible platform and environment for interactive learning and research; design and develop techniques and tools which can be transferred to the NWS community for the operational forecasting or researches, and used in a simulated operational environment.

Accomplishments

The warning decision making process is multi-faceted, often being improved directly by analysis tools or data analysis techniques. CIMMS staff has developed some applications to apply these new tools and techniques into the operational forecasting, training, and research environment. The WDTB Research and Training (WRAT) Lab Toolkit is one of the tools, which fully supports various training strategies, functions and objectives, as well as different simulation types. This tool has been performing as an important role in setting up the lab's configuration and enhancing the interactive learning in workshops, such as the NOAA's NWS Advanced Warning Operations Course (AWOC) and the Distance Learning Operations Course (DLOC).

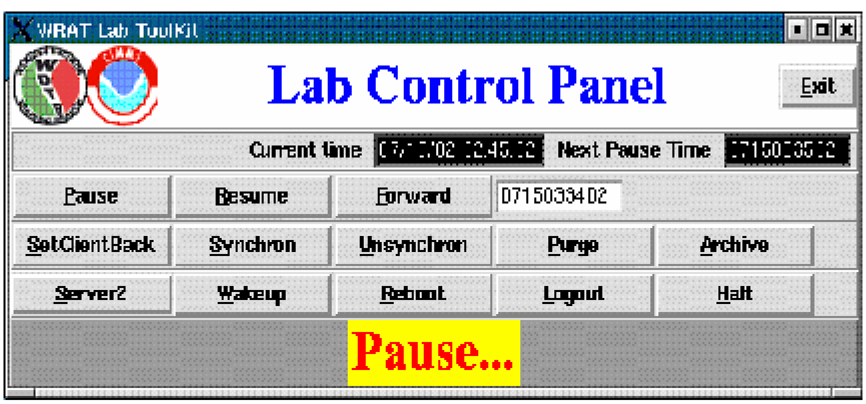
Two other tools recently updated by CIMMS researchers are the Weather Case Browser and the Sounding Toolkit. The Weather Case Browser is a tool developed by CIMMS researchers with an easy to use graphical user interface (GUI) for researchers and instructors to select real time events and archived cases, which could be selected through three categories: the case date, case type and case location. The Sounding Toolkit, another application released by CIMMS researchers, is an updated sounding analysis program (the current version is 1.6). The new functionality in this application gives operational forecasters more flexibility to generate new convective parameters using D2D (AWIPS display software), allowing for the application of newly developed forecast techniques. Accurate weather forecasts are largely dependent on surface and upper air data. While there are thousands of surface weather observations across the continental United States, there are only about sixty locations where weather balloons take measurements above the ground. The current version of the sounding toolkit includes the tropospheric airborne meteorological data reporting (TAMDAR) data, which allows forecasters and researchers to use more than one hundred airports' upper air data.

This project is ongoing.

Publications

Sounding Toolkit 1.3: http://140.90.90.253/~applications/LAD/generalappinfoout.php3?appnum=1050

Yu, X., N.L. Levit, K.R. Hoggard, and N.A. Mohamad Said, 2005: Experiences towards advanced weather research and training. CD-ROM, *21st International Conference on Interactive Information and Processing Systems (IIPS)*, San Diego, CA. Amer. Meteor. Soc.



The WRAT Lab Toolkit.

Warning Decision-Making Research and Training – *Real-Time System*

Hoggard, Magsig, Mohamad Said, Schlatter, X. Yu (primary – CIMMS at WDTB), NWS/WDTB collaborators

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: CIMMS Task II – WDTB

Objectives

Investigate warning decision making issues with real time events, evoke a better understanding of the warning decision making process, and transfer that knowledge to warning decision makers to improve performance.

Accomplishments

The warning decision making process is multi-faceted, often being improved directly by unique observing systems, data analysis techniques, human factors, or improvements in forecast verification. CIMMS scientists collaborated with the Warning Decision Training Branch (WDTB) on a project to provide various real time data, such as satellite data, radar data, model grid data, point data (including METAR, upper air, profiler, lightning) and Bufr profiles. The WDTB real-time system provides an operationally realistic environment for researchers and instructors to experience various events over the country, and develop skills of warning decision making, and archive these events for future training.

Because of the unique data requirements of the training community, the CIMMS staff is required to create unique solutions and builds up a unique real-time system which involves AWIPS, Local Data Manager (LDM), and collects lots of local data from across the country. This can be used for real-time viewing or briefing, case studying, or as an introduction to AWIPS for students of the University of Oklahoma.

This project is ongoing.

Quantitative Precipitation Estimation and Segregation Using Multiple Sensors – *National Basin Repository and Flash Flood Tools for FFMP in AWIPS*

Arthur (primary – CIMMS at NSSL), **Cox**, Howard, Vasiloff

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: CIMMS Task II – NSSL Project 2

Objectives

Complete development of GIS basin datasets with hydrologic connectivity attributes for the Flash Flood Monitoring and Prediction (FFMP) System, provide technical support and assistance to NWS Forecast Offices for their dataset customization efforts, and establish a National Basin Repository at NSSL.

Accomplishments

FFMP basin datasets with hydrologic connectivity attributes were assembled for the remaining 48 WSR-88D coverage areas for use at the WFOs. With these additional hydrologic connectivity attributes, the basin datasets can be customized at the WFOs using the ArcView GIS Basin Customization Extension (Jendrowski). For the WFO forecasters and other staff interested in customizing their datasets, the ninth and final offering of the Basin Customization Course was taught at COMET in September 2004. NSSL continues to provide technical support to numerous WFOs and other FFMP basin dataset users to assist them in understanding and/or customizing their dataset(s). This support ranges from e-mail and phone assistance to performing various customization tasks at NSSL.

The creation of a National Basin Repository is underway to house the FFMP basin dataset and associated GIS data. This data will be displayable and downloadable through a web interface powered by ESRI's ArcIMS and Data Delivery Extension. Previous FFMP basin datasets were developed on a radar-centric basis, but future versions of FFMP capable of ingesting multi-sensor precipitation estimates will require greater flexibility in the domain definition. The web interface will allow users to specify a domain for downloading FFMP and other datasets for use in AWIPS. The FFMP basin dataset is currently being updated to ensure its basins and their hydrologic connectivity attributes are seamless throughout the nation. Computer server hardware and communications infrastructure for the repository have been established, and the ESRI software is currently being implemented.

This project is ongoing.

Publications

Arthur, A.T., G.M. Cox, N.R. Kuhnert, D.L. Slayter, and K.W. Howard, 2005: The National Basin Delineation Project. *Bull. Amer. Meteor. Soc.*, accepted.

Severe Weather Warning Research and Application Development – *Enhanced Hydrometeor Classification Algorithm for Dual-Polarimetric Radar*

Scharfenberg (CIMMS at NSSL)

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: CIMMS Task II – NSSL Project 3

Objectives

Code enhanced hydrometeor classification and surface precipitation type algorithms.

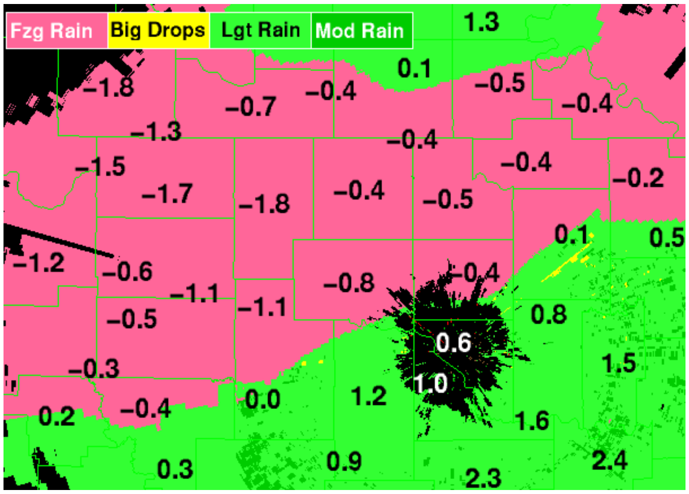
Accomplishments

An enhanced hydrometeor classification algorithm for dual-pol radar was developed which uses numerical model thermodynamic data to supplement the dual-pol radar information. In addition, a surface precipitation type algorithm was developed which uses dual-pol, numerical model, and surface temperature data to estimate surface precipitation types (see figure below). These algorithms were successfully developed using WDSS-II before June 30th and are now undergoing test and evaluation.

This project is ongoing.

Publications

Scharfenberg, K. A., and V. Lakshmanan, 2004: The use of NWP data in polarimetric hydrometeor classification. CD-ROM, *11th Conf. on Aviation, Range, and Aerospace Meteorology*, Hyannis, MA, Amer. Meteor. Soc., P5.7.



A surface precipitation type algorithm developed in WDSS-II, which uses data from dual-polarimetric radar, numerical models, and surface temperature reports (overlay).

Severe Weather Warning Research and Application Development – *Polarimetric Radar Applications*

Scharfenberg (primary – CIMMS at NSSL)**, Burgess, Forren, Krause**

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: CIMMS Task II – NSSL Project 3

Objectives

Conduct off-line and real-time studies on the effect of a 3 dB sensitivity loss to the WSR-88D; deliver and document dual-polarimetric radar hydrometeor classification algorithm; deliver and document dual-polarimetric quantitative precipitation estimation algorithm.

Accomplishments

A test was performed to estimate the operational impact of a 3 dB sensitivity loss to the WSR-88D, which is expected to occur due to the upgrade of the network to include dual-polarimetric technology. This project required the development of software in the ORPG system to simulate the 3 dB sensitivity loss, a comparative study (before/after simulated desensitization) of several archived cases, and a real-time test in which the desensitized data were provided to NWS WFO forecasters for their comparative evaluation. The tests were conducted (before June 30th) and reports of the off-line and real-time studies, including feedback forms from forecasters, were delivered to the ROC (after June 30th). Also, preparation of the latest build of the NSSL dual-polarimetric hydrometeor classification algorithm, and supporting documentation, was ongoing as of June 30th and will be delivered to the ROC later this year. And, the latest build of the NSSL dual-polarimetric quantitative precipitation estimation algorithm, and supporting documentation, were prepared and delivered to the ROC by June 30th.

This project is ongoing.

Publications

Scharfenberg, K.A., V. Lakshmanan, and S. E. Giangrande, 2005: Development and testing of polarimetric radar applications in WDSS-II. CD-ROM, *21st Conf. on Interactive Information Processing Systems (IIPS) for Meteorology, Oceanography, and Hydrology*, San Diego, CA, Amer. Meteor. Soc., 5.10.

Investigation into the Use of Warning Decision Support Systems for Improving Hazardous Weather Detection, Warnings, and Forecasts – *WDSS-II ITR: A Real Time Mining of Integrated Weather Data*

Lakshmanan (primary – CIMMS at NSSL)**, Smith, Stumpf,** Hondl, **Brogden, Kerr, Song, Toomey, Manross, Scharfenberg,** Witt

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: CIMMS Task II – NSSL Project 4 and NSF

Objectives

Create automated techniques for fusing data from multiple radars, models and other sensors in real-time; extract useful weather information from multi-radar, multi-sensor data in real-time; create innovative ways of presenting that information to weather forecasters and decision makers; and disseminate the information in formats that existing GIS systems and decision-support tools can utilize.

Accomplishments

We demonstrated the ability to ingest, in real-time, radar data from all the WSR-88D radars in the continental United States and to perform a number of automated data mining tasks on this data. The reflectivity data are quality-controlled; the velocity data are dealiased; shear is determined; areas of rotation are tracked; hail is diagnosed -- all in real-time on constantly arriving data. This involved the creation of real-time automated algorithms for radar quality control, shear determination, rotation accumulation, storm tracking, hail estimation, multi-Doppler wind field retrieval and total lightning density.

We developed innovative ways of presenting this information in 3D. Called "dynamic cross-sections", this mode of display has been picked to be implemented in the NWS's AWIPS system. Products created by automated algorithms are disseminated in geo-referenced format for use by AWIPS, and for the general public, to Google Earth.

This project is ongoing.

Publications

Lakshmanan, V 2004: A separable filter for directional smoothing. *IEEE Geosc. and Remote Sensing Letters*, **1**, 192-195

Lakshmanan, V., T. Smith, K. Hondl, G. J. Stumpf, and A. Witt, 2005: A real-time, three dimensional, rapidly updating, heterogeneous radar merger technique for reflectivity, velocity and derived products. *Wea. Forecasting*, in review.

Lakshmanan, V., T. Smith, G. J. Stumpf, and K. Hondl, 2005: The warning decision support system - integrated information (WDSS-II). *Wea. Forecasting*, in review.

Lakshmanan, V., I. Adrianto, T. Smith, and G. Stumpf, 2005a: A spatiotemporal approach to tornado prediction. *Int'l Joint Conf. on Neural Networks*, Montreal, Quebec.

Lakshmanan, V., K. Hondl, D. MacGorman, and G. Stumpf, 2004: The user of lightning mapping array data in WDSS-II. CD-ROM, *22nd Conf. on Severe Local Storms*, Amer. Meteor. Soc., Hyannis, MA, P14.3.

Lakshmanan, V. and G. Stumpf, 2005: A real-time learning technique to predict cloud-to-ground lightning. CD-ROM, *Fourth Conf. on Artificial Intelligence Applications to Environmental Science*, Amer. Meteor. Soc., San Diego, J5.6.

Lakshmanan, V., G. Stumpf, and A. Witt, 2005b: A neural network for detecting and diagnosing tornadic circulations using the mesocyclone detection and near storm environment algorithms. CD-ROM, *21st International Conf. on Information Processing Systems*, Amer. Meteor. Soc., San Diego, J5.2.

Lakshmanan, V. and M. Valente, 2004: Quality control of radar reflectivity data using satellite data and surface observations. CD-ROM, *20th International Conf. on Information Processing Systems*, Amer. Meteor. Soc., Seattle, 12.2.

Adrianto, I., T. M. Smith, K. A. Scharfenberg, and T. B. Trafalis, 2005: Evaluation of various algorithms and display concepts for weather forecasting. CD-ROM, *21st Conference on Interactive Information Processing Systems*, Amer. Meteor. Soc., San Diego, CA.

Green, J.S., V. Lakshmanan and T. M. Smith, 2005: Quantitative analysis of different methods for merging radar reflectivity data. *4th AMS Student Conf.*, Amer. Meteor. Soc., San Diego, CA, P1.13.

Smith, T.M. and K. L. Elmore, 2004: The use of radial velocity derivatives to diagnose rotation and divergence. CD-ROM, *11th Conf. on Aviation, Range, and Aerospace*, Hyannis, MA, Amer. Meteor. Soc., P5.6.

Smith, T. M.**,** K. L. Elmore, and S. A. Dulin, 2004: A damaging downburst prediction and detection algorithm for the WSR-88D. *Wea. Forecasting*, **19**, 240-250.

Stumpf, G. J., T. M. Smith and J. Hocker, 2004: New hail diagnostic parameters derived by integrating multiple radars and multiple sensors. CD-ROM, *22nd Conf. on Severe Local Storms*, Hyannis, MA, Amer. Meteor. Soc., P7.8.

Ortega, K. L., T. M. Smith, G. J. Stumpf, J. Hocker, and L. López, 2005: A comparison of multi-sensor hail diagnosis techniques (2005 - 21IIPS). CD-ROM, *21st Conference on Interactive Information Processing Systems (IIPS) for Meteorology, Oceanography, and Hydrology*, Amer. Meteor. Soc., P1.11.

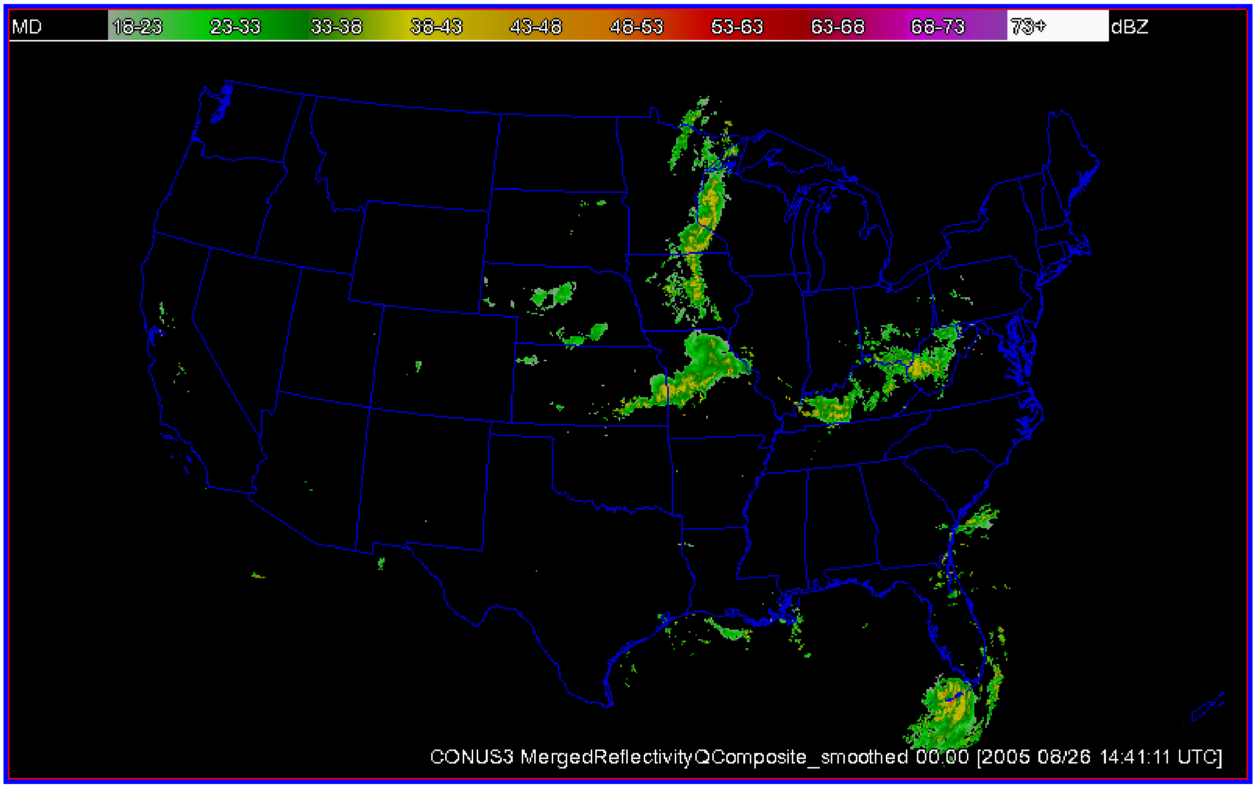
Scharfenberg, K. A., D. J. Miller, D. L. Andra, Jr., and M. P. Foster, 2004: Overview of spring 2004 WDSS-II demonstration at WFO Norman. CD-ROM, *22nd Conf. on Severe Local Storms,* Hyannis, MA, Amer. Meteor. Soc., 8B.7.

Scharfenberg, K. A. and V. Lakshmanan, 2004: The use of NWP data in polarimetric hydrometeor classification. CD-ROM, *11th Conf. on Aviation, Range, and Aerospace Meteorology*, Hyannis, MA, Amer. Meteor. Soc., P5.7.

Scharfenberg, K. A., D. J. Miller, D. L. Andra, Jr., and M. P. Foster, 2004: Overview of spring 2004 WDSS-II demonstration at WFO Norman. CD-ROM, *22nd Conf. on Severe Local Storms*, Hyannis, MA, Amer. Meteor. Soc., 8B.7.

Scharfenberg, K. A., V. Lakshmanan, and S. E. Giangrande, 2005: Development and testing of polarimetric radar applications in WDSS-II. CD-ROM, *21st Conf. on Interactive Information Processing Systems (IIPS) for Meteorology, Oceanography, and Hydrology,* San Diego, CA, Amer. Meteor Soc., 5.10.

Scharfenberg, K. A., T. M. Smith and G. J. Stumpf, 2005: The testing of NSSL multi-sensor applications and data from prototype platforms in NWS forecast operations. CD-ROM, *21st Conf. on Weather Analysis and Forecasting*, Washington, DC, Amer. Meteor Soc., 6A.2.



High-resolution radar data from all the WSR-88D radars in the Continental United States are fused at 1km resolution every 2 minutes to create this real-time product.

Investigation of Synoptic and Mesoscale Meteorological Processes Associated with Hazardous Weather – ***SPC/NSSL Hazardous Weather Testbed Spring Program***
Kain (primary – CIMMS at NSSL)**, Baldwin**, Weiss, Bright, **J. Levit**

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: CIMMS Task II – NSSL Project 6

Objectives
Design and execute an annual collaborative program that allows forecasters to evaluate new tools or concepts that emanate from the research community, while immersing research scientists in the challenges, needs, and constraints of the operational forecasting environment.

Accomplishments
The NOAA Hazardous Weather Testbed in conducted its annual Spring Program from 18 April through 3 June 2005. More than 60 forecasters, research scientists, and university faculty from around the country participated in the program. The goals were to evaluate the operational utility of several experimental versions of the high resolution Weather Research and Forecasting (WRF) model during severe weather episodes, provide feedback to model developers on strengths and weaknesses of the different versions, enhance collaboration between the forecasting and research communities, and accelerate the transfer of new science and technology to operations.

Each of these goals has been addressed. Preliminary results from the program suggest that WRF model output adds value to the current suite of operational model guidance and shows promise in helping to improve forecasts of hazardous weather phenomena. Yet, it is clear that there is significant room for improvement in specific aspects of WRF model forecasts. For example, during the Spring Program numerous systematic biases in model output were identified. These biases appear to be linked to deficiencies in specific physical parameterizations. This information has been shared with model developers and a collaborative effort is underway to better understand and mitigate the model biases.

The 2005 Spring Program has had an immediate impact on operational forecasting at the SPC. A group of seven SPC forecasters participated directly in the program and contributed to an in-depth analysis of the experimental convection-resolving output. The rest of the SPC staff was indirect beneficiaries of the program as the high-resolution output was made available to all SPC forecasters during the program. Because of the positive feedback received during the program, EMC has agreed to continue running their high-resolution model indefinitely. Furthermore, on the basis of favorable assessments during the 2004 and 2005 Spring Programs, EMC has decided to develop a fully operational convection-allowing model configuration. The Spring Program and its parent organization, the NOAA Hazardous Weather Testbed, have become influential resources for strategic planning within NCEP, significantly influencing trends in operational numerical weather prediction in this country.

Finally, The Spring Program also provides academic researchers with hands-on experience and practical information that often finds its way into formal coursework. For example, several academic participants in the program have indicated that their Spring Program experience would have a significant impact on the specific content of the course that they teach.

This project is ongoing.

Publications

Kain, J. S., S. J. Weiss, J. J. Levit, M. E. Baldwin, and D. R. Bright, 2005: Examination of convection-allowing configurations of the WRF model for the prediction of severe convective weather: The SPC/NSSL Spring Program 2004. *Wea. Forecasting*, accepted.

Kain, J. S., S. J. Weiss, M. E. Baldwin, G. W. Carbin, D. A. Bright, J. J. Levit, and J. A. Hart, 2005: Evaluating high-resolution configurations of the WRF model that are used to forecast severe convective weather: The 2005 SPC/NSSL Spring Program. CD-ROM, *21st Conf. on Weather Analysis and Forecasting/17th Conf. on Numerical Weather Prediction*, Washington, D. C., Amer. Meteor. Soc., 2A.5.

Kain, J. S., S. J. Weiss, G. W. Carbin, M. E. Baldwin, D. R. Bright, J. A. Hart, and J. J. Levit, 2005: Comparisons of Different WRF Configurations in a Severe Weather Forecasting Environment: The 2005 SPC/NSSL Spring Program. CD-ROM, *2005 WRF/MM5 Users' Workshop*, NCAR, paper 11.7.

Weiss, S. J., J. S. Kain, J. J. Levit, M. E. Baldwin, and D. R. Bright, 2004: Examination of several different versions of the WRF model for the prediction of severe convective weather: The SPC/NSSL Spring Program 2004. CD-ROM, *22nd Conf. on Severe Local Storms*, Hyannis, MA, Amer. Meteor. Soc., paper 17.1

SPC Forecaster/Science and Operations Officer Steve Weiss and FSL Research Meteorologist John Brown assess the potential for severe thunderstorms during the 2005 SPC/NSSL Spring Program.

Investigation of Synoptic and Mesoscale Meteorological Processes Associated with Hazardous Weather – *Forecast Verification*

Baldwin (primary – CIMMS at NSSL), **Elmore**, **Kain**, **Schultz**

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: CIMMS Task II – NSSL Project 6

Objectives

Develop new and unique verification strategies for forecasts containing realistic detail. Maintain and continue to build a database of forecasts and observations for ongoing verification studies.

Accomplishments

Data collection procedures have continued for precipitation forecasts from experimental versions of the WRF model running at CAPS, NCEP, NSSL and NCAR. These data are available for verification studies using analyses of both radar observations and the so-called "Stage IV" high-resolution multi-sensor precipitation fields from NCEP, which have also been archived. In particular, diagnostic fields of reflectivity from the experimental WRF runs during the 2005 NSSL/SPC Spring Program were archived along with the national mosaic of 2 km base reflectivity from the NEXRAD network.

Development of new verification techniques has also continued at NSSL. In order to obtain more meaningful verification information, an event- or object-oriented approach to verification continues to be developed. The object-oriented verification approach compares characteristics of meteorological phenomena (objects) that can be identified in forecast and observed spatial fields. Automated procedures for identifying, analyzing, and classifying rainfall systems have been established. The automated classification procedure uses statistically-based attributes related to rainfall intensity and spatial organization to place rainfall systems into linear, cellular, or stratiform classes. Once systems have been identified and characterized, comparison rules are established in order to define missed events, false alarms, and matching pairs of forecast-observed objects. Other methods of analyzing the errors in realistic, high-resolution forecast fields are also being developed. The spatial distribution of forecast biases has been analyzed by applying basic statistical tools. Appropriate corrections are made for temporal and spatial degrees of freedom, yielding the spatial distribution of 95% confidence intervals about the mean error at each grid point. These 2-D plots of mean error can be used by forecasters to improve the model guidance that they use in the preparation of their forecasts.

This project is ongoing.

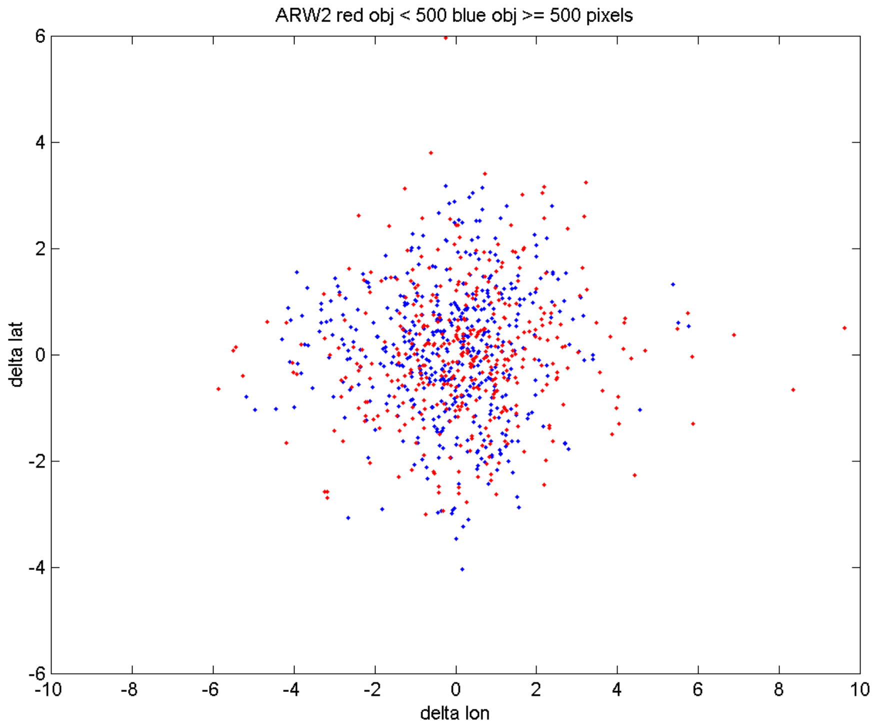
Publications

Baldwin, M. E., S. Lakshmivarahan, and J. S. Kain, 2005: Development of an automated classification procedure for rainfall systems. *Mon. Wea. Rev.*, **133**, 844-862.

Banacos, P. C., and D. M. Schultz, 2005: The use of moisture flux convergence in forecasting convective initiation: Historical and operational perspectives. *Wea. Forecasting*, **20**, 351-366.

Elmore, K. L., D M Schultz, and M. E. Baldwin, 2005: Field significance revisited: Spatial bias errors in forecasts as applied to the Eta Model. *Mon. Wea. Rev.*, accepted.

Schultz, D. M., K. L. Elmore, and M. E. Baldwin, 2005: The behavior of synoptic-scale errors in the Eta Model. *Mon. Wea. Rev.*, submitted.



Position errors (degrees lat/long) for precipitation objects in 2km ARW output with matching observed objects.

Investigation of Synoptic and Mesoscale Meteorological Processes Associated with Hazardous Weather – *Investigation of Methods to Provide Improved Forecasts of Near Surface Conditions through use of Ensemble Forecasts*

Stensrud (primary - NSSL), **Yussouf**, **Baldwin**

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: CIMMS Task II – NSSL Project 6 and NOAA/OAR Special Projects Initiative

Objectives
Investigate methods to post-process a multimodel short-range ensemble forecasting system to obtain improved predictions of near surface variables (e.g., 2-m temperature and dewpoint temperature, and 10-m winds); also investigate methods to improve upon precipitation forecasts from a multimodel short-range ensemble forecasting system.

Accomplishments
A multimodel short-range bias-corrected ensemble (BCE) forecasting system, created as part of NOAA's New England High Resolution Temperature Program (NEHRTP) during the summer of 2004, has been evaluated. The purpose is to extend the BCE approach for accurate predictions of near surface variables at any given location within the model domain. Forecast variables (i.e. 2-m temperature, 2-m dewpoint temperature and 10-m wind speed) calculated from BCE approach at the NWS observation station locations are used to interpolate at specified locations by applying a Cressman weighting scheme. Results are verified against independent observations provided by various state, local, and commercial mesonets. It is found that the performance of extended BCE is competitive with the original BCE approach. The probabilistic information provided by the extended BCE also is found to be very similar to that provided by the BCE approach, both yielding forecasts that are quite reliable and skillful for the thresholds examined. Thus, forecasts for towns and cities that do not presently benefit from the

availability of post-processed statistical model output can easily be provided from the raw ensemble forecasts, routine NWS surface observations, and a few minutes of computer time. Simple techniques such as the BCE and EBCE to bias-corrected ensemble forecasts should be more fully explored and tested in forecast operations to help provide useful and accurate guidance forecasts of many near surface variables to the public.

A simple binning technique has been developed to adjust quantitative precipitation forecasts (QPFs) from a multimodel short-range ensemble forecasting system during the summer of 2004. In this technique, the QPFs and NCEP stage II multi-sensor observations from the past complete 12 days are used to adjust today's precipitation forecast. These adjustments are done individually to each of 16 ensemble members for the 95 days studied. Results indicate that the adjusted ensemble forecast holds the potential of improved guidance in forecasting the probability of precipitation exceeding various threshold values. This is true for all 3-, 6-, 12-, 24- and 48-h precipitation forecasts. Brier skill score and the area under the ROC curve also indicate that this technique provides useful forecasts with high skill and accuracy. Furthermore, it is also found that the performance of the forecasts progressively increases with increased accumulation period. This simple post-processing scheme is very promising in providing useful and reliable probabilistic guidance of rainfall events to the end users.

This project is ongoing.

Publications

Stensrud, D. J., and N. Yussouf, 2005: Bias-corrected short-range ensemble forecasts of near surface variables. *Meteor. Appl.,* **12**, in press.

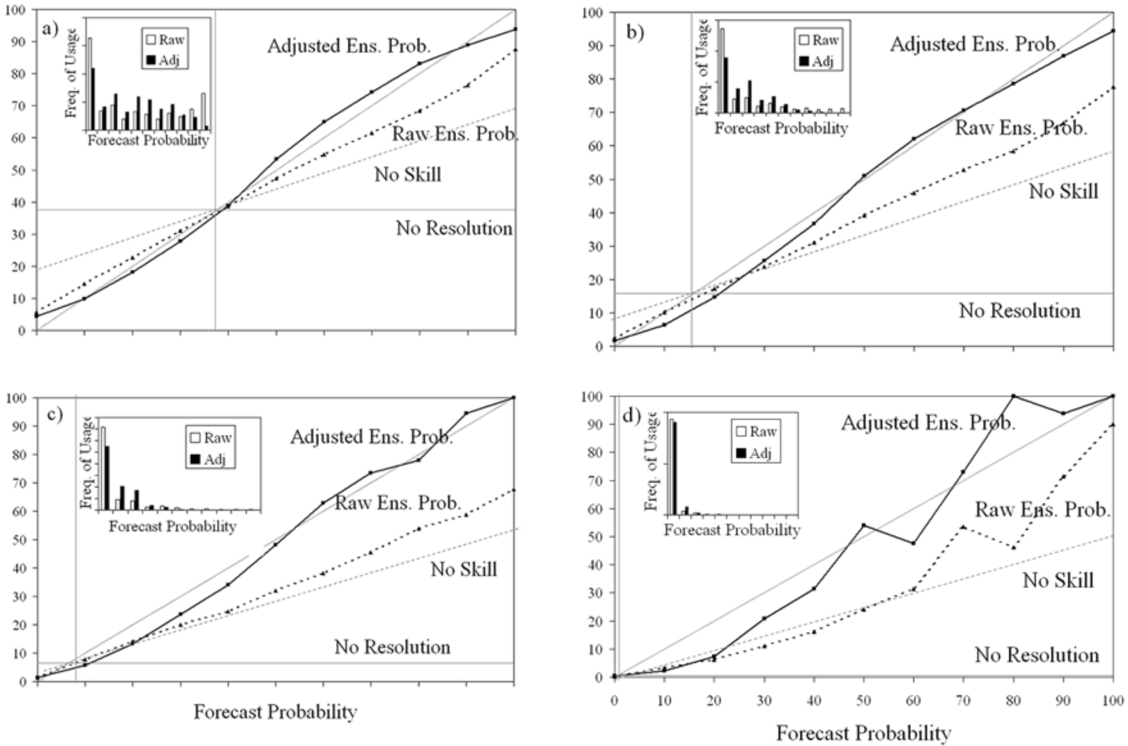
Yussouf, N., and D. J. Stensrud, 2005: Prediction of Near Surface Variables at Any Location from a Bias-Corrected Ensemble Forecasting System. *Mon. Wea. Rev.*, submitted.

Yussouf, N.**,** D.J. Stensrud, and S. Lakshmivarahan, 2004: Cluster analysis of multimodel ensemble data over New England. *Mon. Wea. Rev.*, **132**, 2452-2462.

Nutter, P.**,** D. Stensrud, and M. Xue, 2004: Effects of coarsely resolved and temporally interpolated lateral boundary conditions on the dispersion of limited-area ensemble forecasts. *Mon. Wea. Rev.,***132**, 2358–2377.

Nutter, P., M. Xue, and D. Stensrud, 2004: Application of lateral boundary condition perturbations to help restore dispersion in limited-Area ensemble forecasts. *Mon. Wea. Rev.,***132**, 2378–2390.

Godfrey, C.M.**,** D.J. Stensrud, and L.M. Leslie, 2005: The influence of improved land surface and soil data on mesoscale model predictions. CD-ROM, *19th Conf. on Hydrology*, San Diego, CA, Amer. Meteor. Soc., 4.7.



Attribute diagrams for 48-h adjusted (solid line) and raw (dashed line) 16 member ensemble probabilities for precipitation equal to or exceeding (a) 0.10 in., (b) 0.40 in., (c) 0.80 in., and (d) 2.0 in. Inset histogram indicates the frequency of usage of each forecast probability category for the adjusted ensemble probabilities (black bar) and raw ensemble probabilities (white bar)..

Investigation of Synoptic and Mesoscale Meteorological Processes Associated with Hazardous Weather – *Refinement and Experimental Application of the Kain-Fritsch Convective Parameterization*

Kain (CIMMS at NSSL)

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: CIMMS Task II – NSSL Project 6

Objectives

Refine and test new applications of the Kain-Fritsch convective parameterization and to consult with worldwide users of the scheme.

Accomplishments

The Kain-Fritsch (KF) convective parameterization, originally designed for numerical weather prediction, was tested in numerical predictions of regional climate. It was found that the simulated regional climatology of mesoscale convective systems could be improved considerably by modifying the cloud model within the KF scheme. Specifically, when the scheme's updraft mass flux profiles were altered so that mid-level hydrometeor detrainment increased and convective heating maximized lower in the troposphere, the skill of seasonal forecasts of organized convective activity improved markedly. This work has practical implications for more realistic regional climate predictions and it provides important clues about the physical mechanisms of convective organization and propagation in models with parameterized convection.

Work continued to support operational forecasts and new developments with the KF scheme in operational models at NCEP and elsewhere. Through consultation with NCEP scientists at EMC and SPC, dataflow was established for the SPC to import operational forecasts from a modified version of the Eta model that uses the KF scheme. Technical consultation continues with numerous domestic and international users of the KF scheme.

This project is ongoing.

Publications

Kain, J. S., 2004: The Kain-Fritsch convective parameterization: An update. *J. Appl. Meteor.,* **43**, 170-181.

Anderson, C. J., R. W. Arrit, and J. S. Kain, 2006: Tests of a hybrid convective parameterization in a regional climate model. *J. Hydrometeor*., submitted.

Investigation of Synoptic and Mesoscale Meteorological Processes Associated with Hazardous Weather – *Comparison of Triangulation and Pentagon Methods for Estimating Divergence*

Spencer (primary – CIMMS at NSSL), Dubois

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: CIMMS Task II – NSSL Project 6

Objectives

Compare the triangle and pentagon methods for estimating divergence from irregularly distributed surface wind observations.

Accomplishments

By sampling analytic fields of cyclones and anticyclones of various wavelengths using a hypothetical surface network whose spatial distribution mimics the distribution of a real network, we find that the triangle method for estimating divergence (which assumes a linear variation of the wind field between neighboring stations) outperforms the pentagon method (which assumes a quadratic variation of the wind field between neighboring stations) for undersampled and marginally well-sampled waves, whereas for well-sampled waves, the pentagon method is superior. Apparently, for the smaller waves, the linearity assumption over the relatively small triangles is superior to the quadratic assumption over the relatively large pentagons. The opposite is true for the larger waves.

Also, we find that when the irregularly distributed divergence estimates from each of the methods are analyzed onto a regular grid, those gridded estimates obtained from the triangle method are superior to those from the pentagon method for all wavelengths considered (see figure below). This behavior is believed to be a consequence of both the number of irregularly spaced divergence estimates (the triangle method generated more than twice the number of divergence estimates than did the pentagon method) and the smoothing effect of the analysis scheme on the somewhat randomly distributed truncation errors of the divergence estimates from the triangle method.

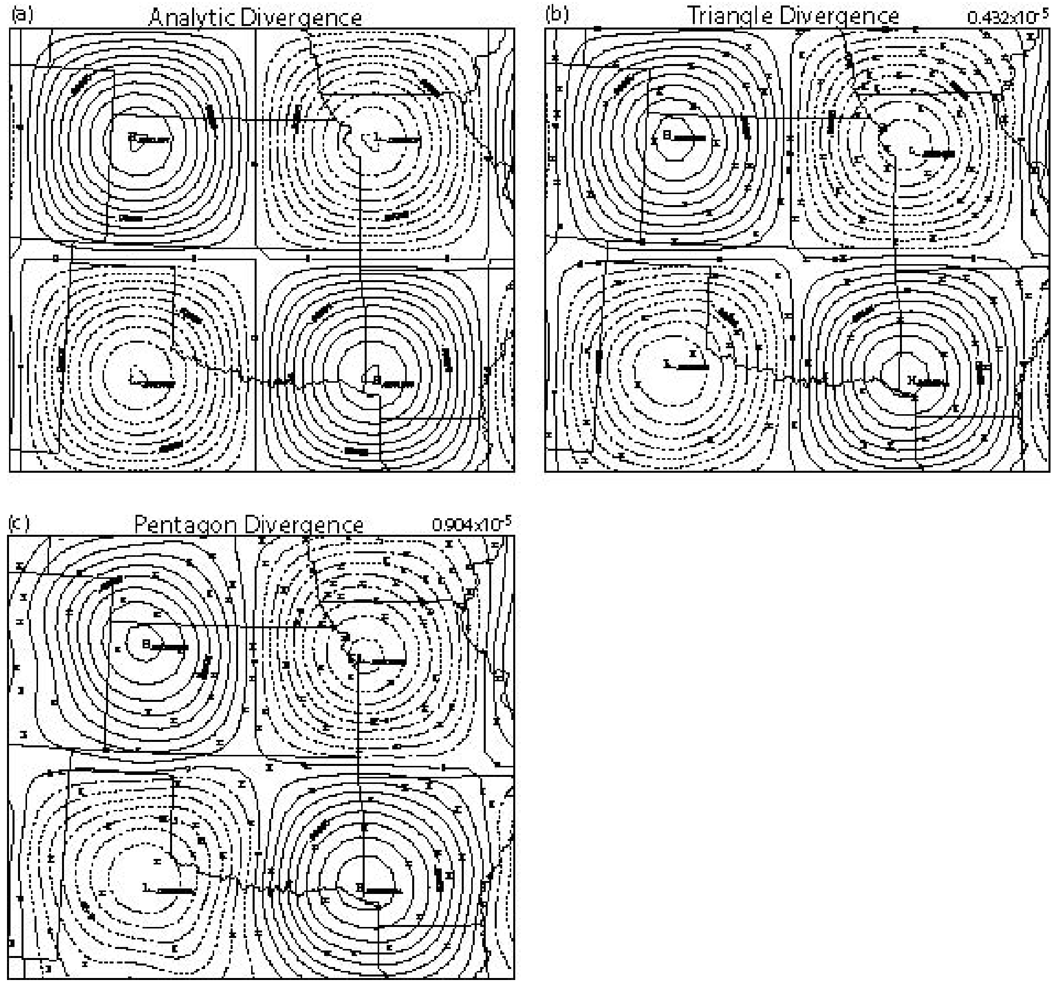
This project has been completed.

Publications

Dubois, J.A., and P.L. Spencer, 2005: Computing divergence from a surface network: Comparison of the triangle and pentagon methods. *Wea. Forecasting*, **20**, 596-608.

Dubois, J.A., and P.L. Spencer, 2005: Estimating divergence from irregularly spaced observations: A comparison of three techniques. *Fourth Annual Student Conf.*, Amer. Meteor. Soc., San Diego, CA, P1.29.

Spencer, P.L., and J. Gao, 2004: Can gradient information be used to improve variational objective analysis? *Mon. Wea. Rev.*, **132**, 2977-2994.



Contour plots of divergence from the (a) analytic function, (b) triangle method, and (c) pentagon method for a marginally well-sampled wave. In (b) and (c), observation locations are indicated by an x. The root mean square errors for the analyses are shown in the upper right corners of (b) and (c).

Investigation of Synoptic and Mesoscale Meteorological Processes Associated with Hazardous Weather – ***Regional-Scale Sounding Network in Support of the North American Monsoon Experiment (NAME)***
Douglas (primary – NSSL)**, Galvez, Mejia, Murillo, Orozco**

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: CIMMS Task II – NSSL Project 6

Objectives
The North American Monsoon Experiment (NAME) is a process study aimed at determining the sources and limits of predictability of warm season precipitation over North America. A regional-scale sounding network was required to complement the enhancements to the regular radiosonde network and aimed at (1) improving estimation of moisture fluxes from the eastern Pacific Ocean into the NAME Tier 1 (Gulf of California and surroundings); (2) improving description of tropical wave variability over Central Mexico and south of the Gulf of California; and (3) improving the description of variations of the quasi-permanent low observed over the southwestern desert of the US and northwestern Mexico.

Accomplishments

As part of the North American Monsoon Experiment (NAME), a network of 22 pilot balloon stations (three in the U.S.) was set in place with help from many institutions and individuals in Mexico and in the states of Arizona and New Mexico. The network was operated for most of the summer with some stations making observations twice a day from June through September. The data collected have been quality checked for internal consistency. Temporal outliers have been identified and spatial outliers are now being identified by means of comparison with neighboring stations. When this process has been completed, the dataset will be released to the research community.

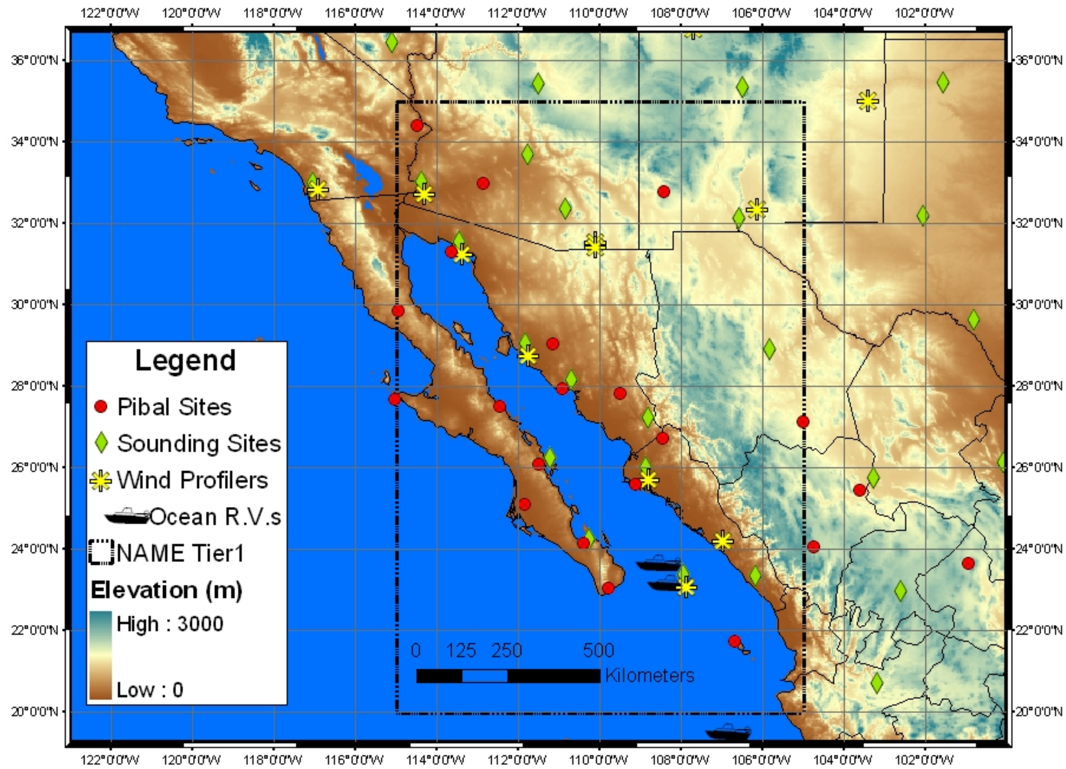
This project is ongoing.

Publications

Douglas M.W., J. M. Galvez, J. F. Mejia, C. Brown, R. Orozco, and C. Watts, 2005: Seasonal evolution of the sea-land breeze circulation and its role in the precipitation climatology of northwestern Mexico. CD-ROM, *Sixth Conf. on Coastal Atmospheric and Oceanic Prediction and Processes*, San Diego, CA, Amer. Meteor. Soc., 3.7.

Mejia J.F. and M. Douglas, 2005: Mean structure and variability of the low-level jet across the central Gulf of California from NOAA WP-3D flight level observations during the North American Monsoon Experiment. CD-ROM, *Sixth Conference on Coastal Atmospheric and Oceanic Prediction and Processes*, San Diego, CA , Amer. Meteor. Soc., 5.8.

Douglas, Michael W., NOAA/NSSL, Norman, OK; and J. F. Mejia: Intensive "porpoising" with a research aircraft to determine atmospheric structure during the SALLJEX and NAME programs, *13th Symposium on Meteorological Observations and Instrumentation*, Savannah, GA, JP1.31, PDF.



Regional-scale pilot balloon network (red dots) established in support of NAME. Other components shown are not part of this particular project. Figure by Dave Gochis (UCAR).

Research on Integration and Use of Multi-Sensor Information in Weather Forecasting –
Science and Technology Infusion
Stumpf (CIMMS at NWS/MDL)

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: CIMMS Task II – NSSL Project 9

Objectives
Facilitate CIMMS/NSSL scientists in developing multiple-sensor severe weather and flash flood warning applications for NWS operational systems; set up an AWIPS Development Environment at CIMMS/NSSL; eventually set up several multi-sensor severe weather testbeds at select NWS forecast offices nationwide.

Accomplishments
The first full year of this new CIMMS/NWS/Meteorological Development Laboratory (MDL) scientist position was completed during this review period. An "AWIPS-Lite" system was installed at NSSL, and is being used for both AWIPS/SCAN application development and evaluation, and for testing the display of external WDSSII grids for WFO testing. New AWIPS/SCAN application development included the development of new hail diagnostic grids, and an evaluation was undertaken in collaboration with the Warning Decision Training Branch and a Research Experience for Undergraduates (REU) student. This information will be used for official NWS training documentation on the new AWIPS application. Using the AWIPS workstation, the first successful integration of NSSL Warning Decision Support System Integrated Information (WDSSII) multiple-sensor severe weather application grids and operational AWIPS data streams was conducted. New multiple-radar/sensor hail diagnostic grids, "rotation tracks" grids (useful for mesocyclone tracking and storm damage surveys), and Oklahoma Lightning Mapping Array (LMA) total lightning grids are being ingested into the NWS Southern Region AWIPS data stream and being broadcast to the WFOs at Norman, Tulsa, and Fort Worth. This is the first step toward the development of a WFO component of the National Weather Center Hazardous Weather Testbed, or "Spring Program", designed to be a proving ground for new severe weather applications to assist short-fused (0-1 hour) warning decisions.

The CIMMS/MDL scientist also co-facilitated the 1st Workshop on Severe Weather Warning Technology, a users' meeting that was conducted at Silver Spring, MD. The objective of the meeting was to review the "state of the science and technology" of NWS severe weather warning assistance tools, to identify gaps in the present methodologies and technologies, to gain expert feedback from the field (including "stories" from the front lines), to discuss the near-term and long-term future trends in AWIPS R&D, and for field forecasters and R&D scientists to help pave the direction for new technological advances. The CIMMS/MDL continued to closely collaborate with the severe weather warning R&D activities at CIMMS and NSSL, in the areas of multiple-sensor severe weather warning applications and new three- and four-dimensional base radar display systems (e.g., the AWIPS Four-dimensional Stormcell Investigator; see figure below) which will eventually be transferred to NWS operations.

This project is ongoing.

Publications
Lakshmanan, V., K. D. Hondl, D. MacGorman, and G. J. Stumpf, 2004: The use of Lightning Mapping Array data in WDSS-II. CD-ROM, 22nd Conference on Severe Local Storms, Hyannis, MA, Amer. Meteor. Soc., P14.3.

Manross, K. L., R. J. Trapp, and G. J. Stumpf, 2004: WSR-88D radar characteristics of quasi-linear convective system tornadoes using the NSSL Severe Storm Analysis Program. CD-ROM, *22nd Conf. on Severe Local Storms*, Hyannis, MA, Amer. Meteor. Soc., 8B.2.

Stumpf, G. J., M. T. Filiaggi, V. Lakshmanan, W. F. Roberts, M. J. Istok, and S. B. Smith, 2004: A four-dimensional radar analysis tool for AWIPS. CD-ROM, *22nd Conf. on Severe Local Storms*, Hyannis, MA, Amer. Meteor. Soc., 8B.6.

Stumpf, G. J., T. M. Smith, and J. Hocker, 2004: New hail diagnostic parameters derived by integrating multiple radars and multiple sensors. CD-ROM, *22nd Conf. on Severe Local Storms*, Hyannis, MA, Amer. Meteor. Soc., P7.8.

Lakshmanan, V., G. J. Stumpf and A. Witt, 2005: A neural network for detecting and diagnosing tornadic circulations using the Mesocyclone Detection and Near Storm Environment Algorithms. CD-ROM, *4th Conf. on Artificial Intelligence Applications to Environmental Science*, San Diego, CA, Amer. Meteor. Soc., J5.2.

Lakshmanan, V., and G. J. Stumpf, 2005: A real-time learning technique to predict cloud-to-ground lightning. CD-ROM, *4th Conf. on Artificial Intelligence Applications to Environmental Science*, San Diego, CA, Amer. Meteor. Soc., J5.6.

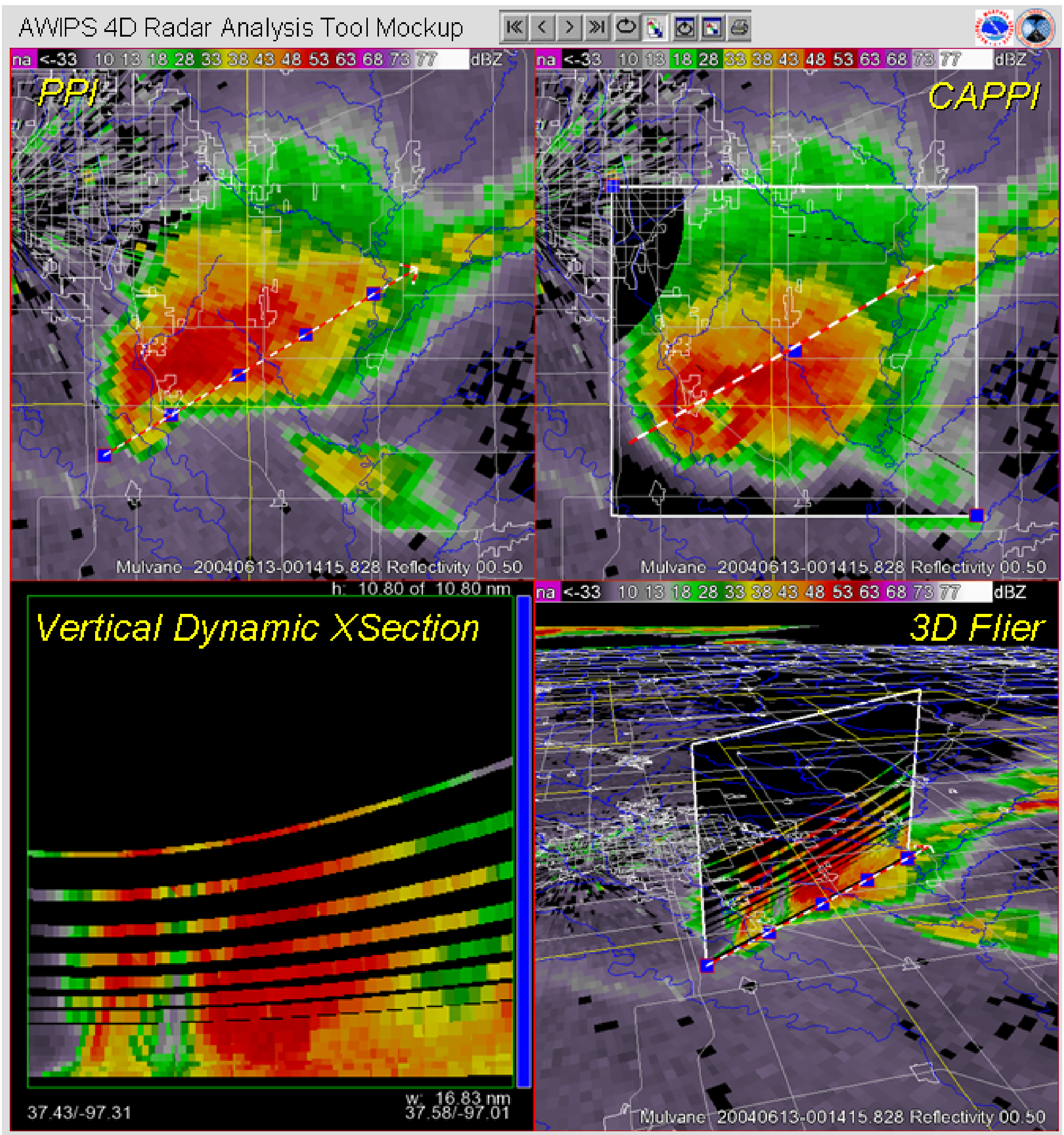
Manross, K. L., J. G. LaDue, and G. J. Stumpf, 2005: The Volume Coverage Pattern Explorer: A new tool for visualizing radar beam paths. CD-ROM, *21st International Conf. on Interactive Information Processing Systems (IIPS) for Meteor., Oceanography*, and Hydrology, San Diego, CA, Amer. Meteor. Soc., 5.5.

Brown, R. A., R. M. Steadham, B. A. Flickinger, R. R. Lee, D. Sirmans, and V. T. Wood, 2005: New WSR-88D volume coverage pattern 12: Results of field tests. *Wea. Forecasting*, **20**, 385-393.

Ortega, K. L., T. M. Smith, G. J. Stumpf, J. Hocker, and L. López, 2005: A comparison of multi-sensor hail diagnosis techniques. CD-ROM, *21st International Conf. on Interactive Information Processing Systems (IIPS) for Meteor., Oceanography, and Hydrology*, San Diego, CA, Amer. Meteor. Soc., P1.11.

Smith, T. M., and G. J. Stumpf, 2005: Multi-sensor storm cell identification and analysis. CD-ROM, *21st International Conf. on Interactive Information Processing Systems (IIPS) for Meteor., Oceanography, and Hydrology*, San Diego, CA, Amer. Meteor. Soc., P1.10.

Stumpf, G. J., S. B. Smith and K. E. Kelleher, 2005: Collaborative activities of the NWS MDL and NSSL to improve and develop new severe weather warning guidance applications. CD-ROM, *21st International Conf. on Interactive Information Processing Systems (IIPS) for Meteor., Oceanography, and Hydrology*, San Diego, CA, Amer. Meteor. Soc., P2.13.



Four-dimensional Stormcell Investigator (FSI) display mockup, showing data from KICT on 12 June 2004.

Advancing Science to Improve Knowledge of Mesoscale Hazardous Weather
Dean (CIMMS at SPC)

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

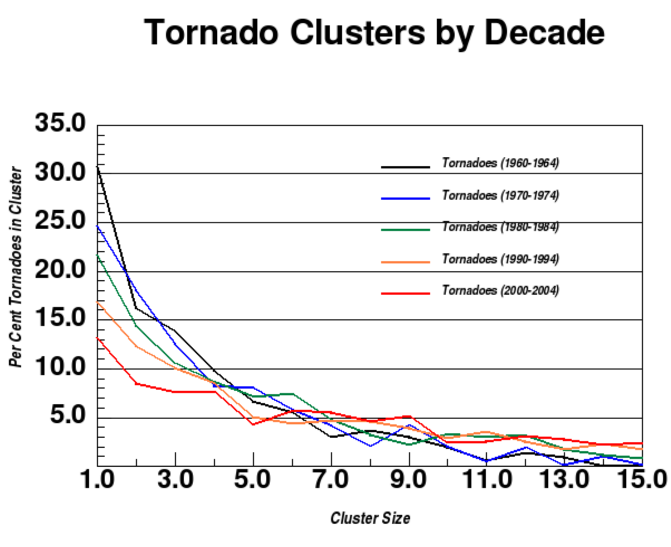
Funding Agency: CIMMS Task II – SPC

Objectives
Study research methodologies that can be used to verify predicted outcomes of meteorological phenomena; present research results to forecasters and other scientists involved in activities related to hazardous weather; assist SPC scientists and managers in science and technology infusion efforts, including data collection and quality control.

Accomplishments
The main focus this year was to develop a timely and robust verification system for SPC convective outlooks and watches. This was accomplished by building a PostgreSQL database in which storm reports and SPC forecasts are stored, where they can be combined by simple database queries to produce a wide range of useful verification results. Development of this database allowed SPC to meet their goal of producing timely verification results for the new county-based watch system. The initial development of the database is mostly complete, but development will be an ongoing process as the verification system becomes more sophisticated.

Another research focus was an analysis of the storm report database, looking for reports that "cluster" together in time and space. Since SPC does not attempt to account for every single severe report with their forecasts, it is important to determine the number and type of reports that occur in groups large enough to meet the criteria of the various SPC forecast products. Preliminary results indicate that the percentage of reports that are unclustered (over the area and time span of a typical watch), or only clustered in small groups, has decreased dramatically in the last 25 years. Also, the percentage of wind and hail reports that are "redundant" (within the same county and within 10 miles and 15 minutes of another report of the same type) has increased from less than 5 percent before 1999 to around 15 percent since 1999, suggesting that at least some of the recent dramatic increase in reports is due to more aggressive reporting policies. These results may have some impact on SPC forecasting criteria and verification methodologies in the future, but more analysis needs to be done and is ongoing.

This project is ongoing.



Percent of tornadoes by decade that occurred in various cluster sizes. Note that the period 2000-2004 had the smallest percentage in small clusters and the largest percentage in larger clusters.

An Investigation of Communicating Weather Information Effectively using the Internet

Minton (primary – CIMMS at SRH)**, Kirkwood**

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: CIMMS Task II – SRH

Objectives

Investigate new applications to increase the capabilities of providing new digital services to the public; investigate enhancements to the back-end web applications, databases, and services that are the backbone of the Southern Region Headquarters web presence, and study the usefulness and cost-effectiveness of new technologies.

Accomplishments

Spanish versions of "Point Forecast" web pages have been created for the Hispanic population (see press release below in "Public Affairs and Outreach" and "Awards"). Also, "Cell Phone" web pages have been created and recently its marine/tropical storm portions recently enhanced. A capability has been developed to provide warning polygons to the next generation radar pages.

This project is ongoing.

Evaluation of Synoptic-Scale Controls on Tornado Outbreaks

Doswell (primary – CIMMS at OU)**,** R. Thompson, Hart, Crosbie, Edwards, **Leslie**, **Richman**, **Ramsay**

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: NSF

Objectives

Collect and rank tornadic and nontornadic severe storm outbreak cases; develop composite charts for both tornadic and nontornadic outbreaks of severe weather for use as initial conditions in two different mesoscale models.

Accomplishments

An important tornado forecasting problem is to decide whether or not a particular synoptic-scale system is going to produce a significant outbreak of tornadoes. Although much work has been done on individual case studies over the decades since tornado forecasting began in the 1950s, this issue remains problematic for forecasters. In collaboration with Richard Thompson, John Hart, Casey Crosbie, and Roger Edwards of the Storm Prediction Center, the project to collect and rank tornadic and nontornadic severe storm outbreak cases and build a database for the study has been completed. A formal publication regarding this first part of the project has been submitted to *Weather and Forecasting*. The phase of this project involving a team doing subjective analyses of all the cases is about to begin.

Work on another aspect of this project has begun, in collaboration with Lance Leslie and Michael Richman of the OU School of Meteorology, and graduate student Hamish Ramsay. This second approach to the problem of synoptic-scale controls on tornado outbreaks has been submitted to NSF for funding support and uses spatial statistics to develop composite charts for both tornadic and nontornadic outbreaks of severe weather for use as initial conditions in two different mesoscale models. A few cases have been run to show that the models can produce reasonably accurate forecasts even without having any subsynoptic-scale input to the initial conditions. The use of proxy variables to determine the model's ability to forecast the difference between tornadic and nontornadic outbreaks of severe weather is being explored using individual case study forecast simulations at time ranges of 24-72 hours.

This project is ongoing.

Publications

Edwards, R., R.L. Thompson, K.C. Crosbie, J.A. Hart, and C.A. Doswell III, 2004: A proposal for modernized definitions of tornado and severe thunderstorm outbreaks. CD-ROM, *22nd Conf. Severe Local Storms,* Hyannis, MA, Amer. Meteor. Soc.

A European Climatology of Severe Weather Related Parameters

Doswell (primary – CIMMS at OU)**,** Romero, Gaya

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: CIMMS

Objectives

Develop a climatology of European severe weather.

Accomplishments

This project was carried out in collaboration with Romualdo Romero of the University of the Balearic Islands and Mr. Miguel Gaya of the INM (the Spanish equivalent of the National Weather Service). It was designed to serve as a starting point for a "synthetic climatology" of European severe weather, and was presented at the European Conference on Severe Storms in Leon, Spain in 2004. The work is in press for publication in *Atmospheric Research*. Results can be viewed at http://ecss.uib.es.

This project has been completed.

Publications

Groenemeijer, P.H., N. Dotzek, F. Stel, H.E. Brooks, C.A. Doswell III, M. Elsom, D.B. Giaiotti, A. Gilbert, A. Holzer, G.T. Meaden, M. Salek, and J. Teittinen, 2004: A data format for severe weather reports to be used in Europe. *European Conf. on Severe Storms*, Leon, Spain. (Abstract only)

Romero, R, M. Gaya, and C.A. Doswell III, 2004: European climatology of severe convective storm environmental parameters: A test for significant tornado events. *European Conf. on Severe Storms*, Leon, Spain. (Abstract only)

Tri-State Tornado Reanalysis

Doswell (primary – CIMMS at OU), Maddox, Johns, Gilmore, Crisp, Hart

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: CIMMS

Objectives

Re-investigate the Tri-State tornado of 18 March 1925.

Accomplishments

An informal group of researchers – also including Bob Maddox (retired NSSL Director), Bob Johns (retired SPC Science and Operations Officer), Matt Gilmore (University of Illinois), Charlie Crisp (NSSL), and John Hart (SPC) – has begun investigating the track of the infamous Tri-State tornado of 18 March 1925, and also reassessing the meteorological setting in which the storm developed. This apparently singular event in U.S. tornado history is, not surprisingly, poorly documented, with several apparent inconsistencies in the existing literature on the subject. Considerable evidence has been amassed regarding the issue of the continuity of the track; new evidence has come to light indicating that the track may be longer than previously thought and that the track may not be as straight as it is often described. Preliminary meteorological analysis has indicated that the actual conditions giving rise to the storm are somewhat different than reported previously in the literature and that other severe storms occurred on that fateful day. Work continues to find more meteorological data and track evidence.

This project is ongoing.

Publications (other publications from Dr. Doswell)

Doswell, C.A. III, 2004: Weather forecasting by humans – Heuristics and decision-making. *Wea. Forecasting*, **19**, 1115-1126.

Brooks, H., C. Doswell III, D. Dowell, R. Holle, B. Johns, D. Jorgensen, D. Schultz, D. Stensrud, S. Weiss, L. Wicker, and D. Zaras, 2003: Severe thunderstorms and tornadoes. Chapter 29, *Handbook of Weather, Climate, and Water: Dynamics, Climate, Physical Meteorology, Weather Systems, and Measurements* (B. R. Colman and T. D. Potter, Eds.), John Wiley and Sons, 575-619.

Parameterizing Cloud-Aerosol Interactions in Regional Forecast Models

Y. Kogan, Mechem (primary – CIMMS at OU)**, Robinson**

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agencies: ONR

Objectives

Formulate improvements in how regional models represent aerosol-cloud-precipitation interactions.

Accomplishments

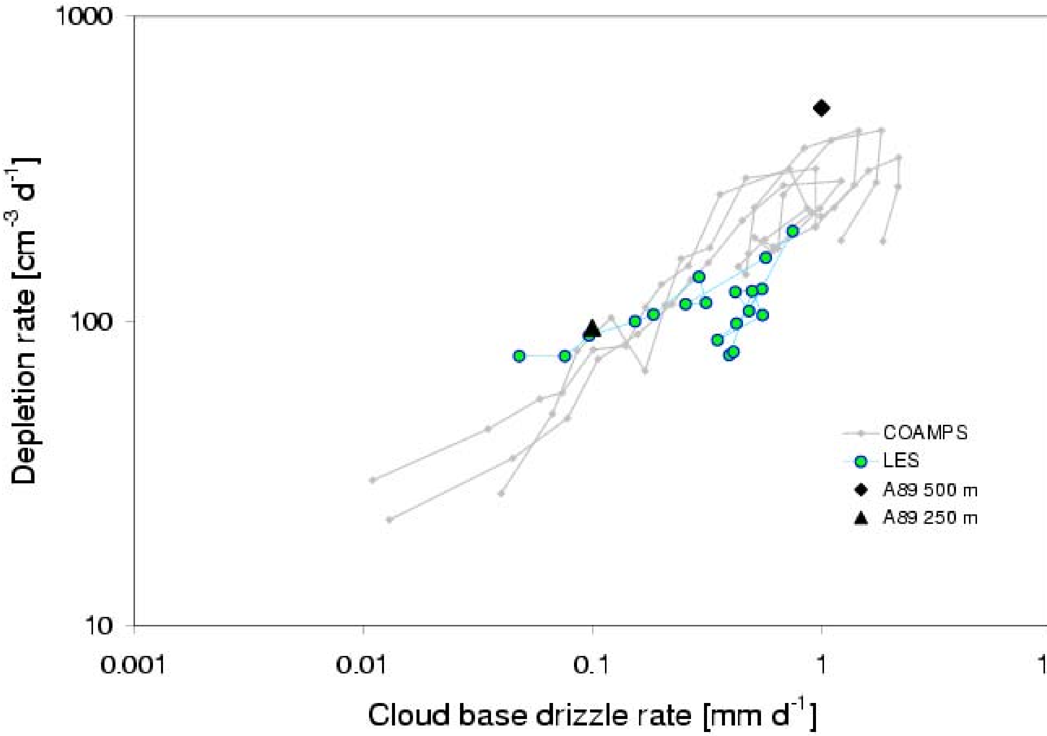
We have built on our previous efforts on representing cloud processing of aerosol using bulk microphysical models. Regional model aerosol depletion rates were calculated from the Naval Research Laboratory's Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS) equipped with the CIMMS bulk drizzle scheme. In an attempt to constrain cloud processing rates calculated from regional model simulations, large eddy simulations (LES) of matching cases were analyzed. The LES model explicitly represents the turbulent dynamics and bin-resolving microphysical processes, which are for the most part parameterized in the regional model. Depletion is calculated in COAMPS from a budget residual of total particle concentration, while in the LES is based on the coagulation process. For the purpose of this comparison the two quantities are equivalent. COAMPS depletion rates compare favorably with the LES, though the range of the LES rates is smaller. As aerosol are consumed by cloud processing, the depletion rate in the LES peaks at somewhat earlier at at a smaller magnitude than in COAMPS, implying that cloud processing may be somewhat self-regulating when a more complete treatment of dynamical and microphysical processes are included. Both COAMPS and LES depletion rates are in the range of theoretical calculations of cloud processing along the lines of Albrecht (1989).

Our group's previous work has emphasized the importance on the precipitation process of representing giant CCN (aerosol particles with radius larger than 1.0 micron) in a bulk microphysical model. A parameterization of giant CCN, which can be straightforwardly implemented into current bulk microphysical schemes, has been formulated. The parameterization is based on first principles and parameters directly measured in observations. The input parameters include total concentration of giant aerosols and the exponent of the Junge power law aerosol distribution. This allows calculation of a water substance source term incorporated into the bulk scheme rainwater equation. The activation problem is straightforward for the giant part of the aerosol spectrum, since nuclei larger than 1.0 micron are easily activated at small values of supersaturation. Tests of the giant CCN parameterization in a large eddy simulation (LES) framework show the correct physical response of the scheme which exhibits increase of drizzle rate as a function of giant CCN concentration consistent with the response in the explicit microphysics formulation.

This project is ongoing.

Publications

Mechem, D. B., and Y. L. Kogan, 2005: Representing cloud processing of aerosols in numerical models. Proc., *15th Atmospheric Radiation Measurement (ARM) Science Team Meeting*, Daytona Beach, FL, U.S. Dept. of Energy.



CCN depletion rate as a function of cloud base drizzle rate for four COAMPS simulations (grey lines) and large eddy simulation (turquoise circles). Depletion is defined as cloud processing via coagulation and is taken from the explicit bin microphysics calculations in the LES and computed in COAMPS from a budget residual of total particle number. The diamond and triangle represent theoretical calculations as in Albrecht (1989) for clouds of thickness 500 m and 250 m, respectively.

Advanced Weather Data Visualization

J. Levit (primary – SPC), **Baldwin**, Ebert, Riley, Song, Hansen

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: NSF

Objectives

Create new computer graphics software to visualize meteorological data in a photo-realistic sense; investigate new techniques for visualizing meteorological data.

Accomplishments

The primary research completed during the period involved upgrading the visualization software package to render several different types of data sets. The software can now render NEXRAD Level-II data and WRF model data containing terrain-following coordinates. Additionally, the system was upgraded to use rendering capabilities existing on the next generation of PC graphics cards.

This project is ongoing.

Publications

Riley, K., Song, Kraus, Ebert, and Levit, 2005: Realistic meteorological visualization of structured non-uniform grids with functionally encoded vertices. *IEEE Computer Graphics and Applications*, accepted.

Rendering of a simulated supercell storm using the WRF model and new graphics visualization software.

Development of a Tool to Aid in Forecasting the Evolution of Late-Morning MCS Activity

Hane (primary – NSSL), Andra, **Carr**, **T. Thompson**

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: UCAR/COMET

Objectives

Develop a tool to improve forecasting the evolution of mesoscale convective systems that occur during late morning hours; improve understanding of how the evolution of these systems is related to their environment.

Accomplishments

An undergraduate student assistant (Therese Thompson) was selected and began working on the project in February of 2005. Most of her work to date has contributed to a climatological study of morning MCSs that have affected the Norman, OK and Dodge City, KS County Warning Areas during June, July, and August of 2001-2004. Cases from the summer of 2005 will be added as they become available. A total of 136 systems were identified during this period, their tracks were documented on maps, initiation locations plotted, occurrences of severe weather documented, and speed and direction of motion recorded. Some of this information has been added to a paper to be presented at the 11th Conference on Mesoscale Processes.

Additional analysis has been completed on systems that occurred during an earlier period (1996-2000). This effort has used discriminant analysis to link classes of system evolution to characteristics of the environment. Results of this analysis were reported in a presentation at the AIRMASS 2005 Conference in April 2005, and will be included in a paper submitted for formal publication (in preparation). These results will also be included in the mesoscale conference paper (October 2005).

This project is ongoing.

Publications:

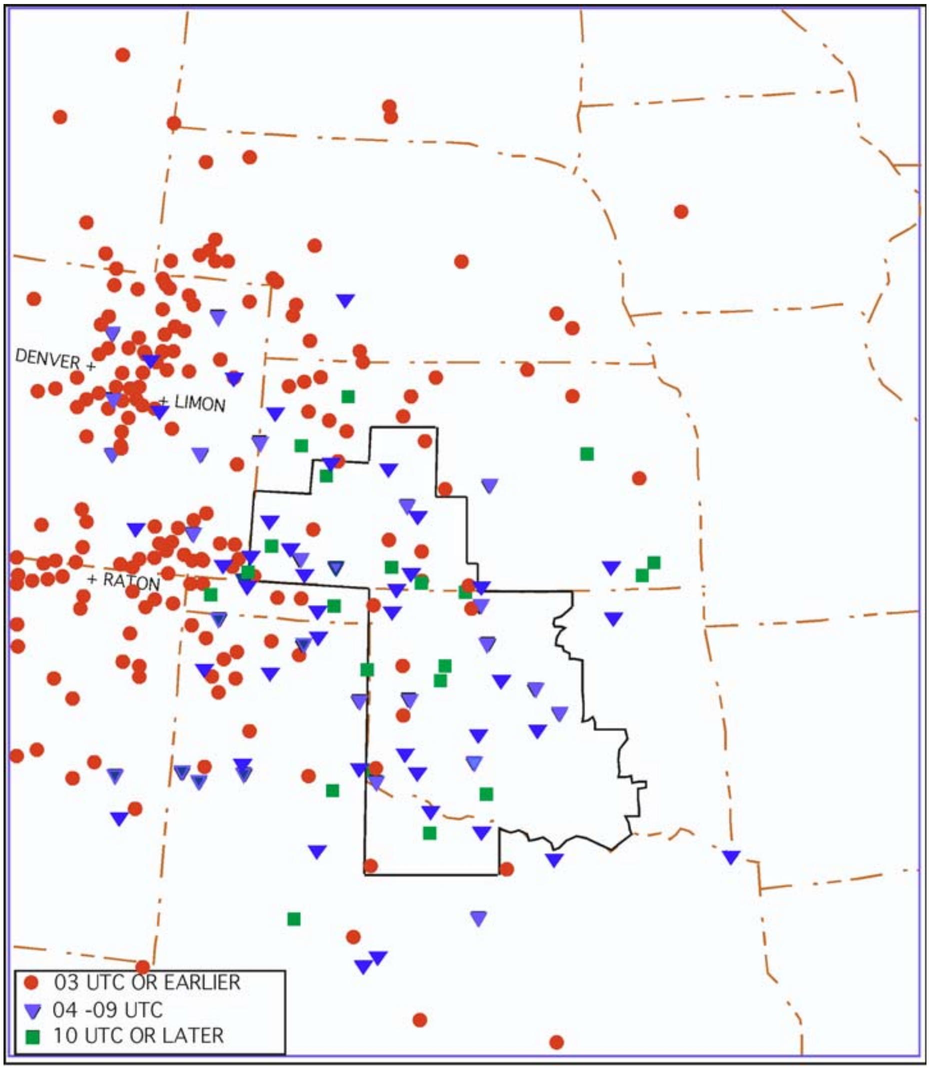
Hane, C. E., D. L. Andra, Jr., K. Trammell, and F. H. Carr, 2005: Development of a tool to aid in forecasting the evolution of Great Plains MCSs during late morning hours. CD-ROM, *AIRMASS 2005 Conf.*, Wichita, KS.

Haynes, J. A., C. E. Hane, D. A. Andra, Jr., F. H. Carr, and R. M. Rabin, 2006: The evolution of morning convective systems over the U. S. Great Plains during the warm season. Part II: A climatology and the influence of environmental factors. *Mon. Wea. Rev.,* in preparation.

Hane, C. E., D. L. Andra, Jr., J. A. Haynes, T. E. Thompson, and F. H. Carr, 2005: On the importance of environmental factors in influencing the evolution of morning Great Plains MCS activity during the warm season. CD-ROM, *11th Conf. on Mesoscale Processes*, Albuquerque, NM, Amer. Meteor. Soc.

Hane, C. E., 2004: Quiescent and synoptically-active drylines: A comparison based upon case studies. *Meteor. and Atmos. Phys.*, **86,** 195-211.

Rabin, R. M., S.F. Corfidi, J.C. Brunner, and C.E Hane, 2004: Detecting winds aloft from water vapor satellite imagery in the vicinity of storms. *Weather*, **59**, 251-257.



Initiation locations for MCSs that affected the Norman, OK and Dodge City, KS County Warning Areas during late morning for the warm seasons of 1996-2004. Time of day of initiation is also indicated by symbol shapes.

Land-Atmosphere Memory Quantified Using Observations from the Oklahoma Mesonet and the NOAH Land Surface Model

Basara (primary – Oklahoma Climatological Survey)**, Crawford**, Illston, Nemunaitis, Monroe, Hunt, **Morris**

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: CIMMS Task III – NOAA OGP

Objectives

Develop a quality controlled data set which involves meteorological and hydrologic observations from Oklahoma Mesonet sites and obtain new insights of land-atmosphere interactions from diagnostic studies using Mesonet data; identify the parameterizations in the NOAH LSM which are sensitive to land surface conditions and use Mesonet data to modify, improve, and test the parameterizations to produce reduced model variability.

Accomplishments

During the research period, progress continued for all objectives of the study. Even so, the bulk of the work was conducted in two main areas. First, new Quality Assurance (QA) techniques were developed and tested for OASIS data. In addition, manual QA was applied to all Mesonet soil moisture data prior to October 2002. As such, all Mesonet soil moisture data collected since 1996 has received the same, robust QA that is currently employed on an operational basis. The result is that the entire soil moisture archive is now deemed research quality to the scientific community and general public.

The second main effort focused on finalizing the results of a number of validation studies, most notably the intercomparison between Mesonet observations and output from the North American Land Data Assimilation System (NLDAS). NLDAS consists of uncoupled land surface models (LSMs) forced with precipitation observations, output from the Eta model data assimilation system (EDAS), and solar radiation from the GOES satellites. Retrospective simulation datasets, provided in collaboration with the NLDAS Group, were used to simulate energy fluxes from the Mosaic and Noah LSMs for the warm season of year 2000. The Oklahoma Mesonet provided data for verifying and quantifying systematic biases in the radiation and surface energy budgets simulated by the Mosaic and Noah LSMs. In terms of a regional approach, these results show that both models captured net radiation very well. However, forcing biases were evident in the intercomparisons of downwelling longwave radiation. In addition, significant biases were found in the sensible and ground heat fluxes. Surface flux biases were attributed to the model configuration, forcing biases, and the onset of drought conditions. Finally, analysis of the regional trends of the components of the surface energy balance simulated by each LSM found that the models overestimated the variation of energy fluxes from west to east across Oklahoma.

This project is ongoing.

Publications

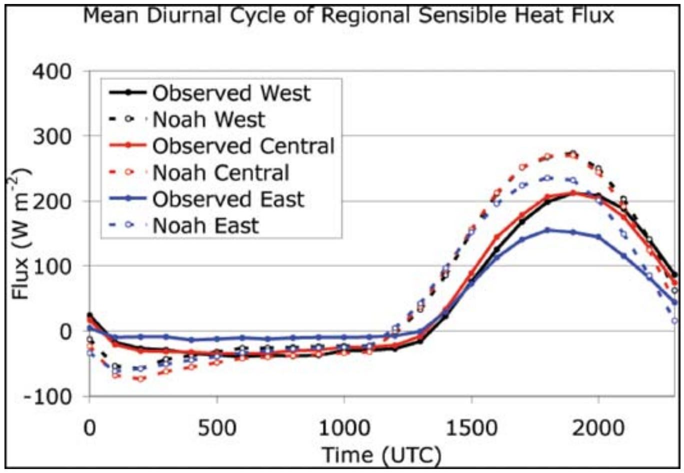
Anderson, M. C., J. R. Mecikalski, R. D. Torn, J. M. Norman, W. L. Kustas, and J. B. Basara, 2004: Disaggregation of Regional Flux Estimates using Landsat Thermal and Visible Band Imagery. *J. Hydromet.*, **5**, 343-363.

Chen, F., K. W. Manning, M. A. LeMone, S. B. Trier, J. G. Alfieri, R. Roberts, J. Wilson, M. Tewari, D. Niyogi, T. W. Horst1, S. P. Oncley, J. B. Basara , and P. D. Blanken, 2005: Evaluation of the Characteristics of the NCAR High-Resolution Land Data Assimilation System During IHOP-02. *J. Hydrometeor.*, submitted.

Illston, B.G., J.B. Basara, and K.C. Crawford, 2004: Seasonal to interannual variations of soil moisture measured in Oklahoma, *Int. J. Climatol*, **24**, 1883 - 1896.

Nemunaitis, K. L., J. B. Basara, B. A. Cosgrove, D. Lohmann, K. E. Mitchell, P. R. Houser, and J. W. Monroe, 2005: Verification of the North American Land Data Assimilation System (NLDAS) using data from Oklahoma Mesonet Sites. *J. Hydromet.*, submitted.

Sun, D., R. Pinker, and J. B. Basara, 2004: Land surface temperature estimation from the next generation Geostationary Operational Environmental Satellite GOES M-Q. *J. Applied Meteor.*, **43**, 363-372.



The mean diurnal cycle of sensible heat flux for candidate days during the warm season of year 2000 from averaging over all OASIS Super Sites and corresponding Noah land surface model (LSM) grid points in the west, central, and east regions of Oklahoma. The results demonstrate that while the Noah LSM overestimated sensible heat flux, it correctly captured the natural east-west gradient.

Contribution to the WRF Model Development by CAPS

Xue (primary - CAPS), Gao, Brewster, Hu, **Liu**

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: Task III – FAA

Objectives

Develop the radar data assimilation components for the WRF 3DVAR system and contribute to the development and testing of WRF model system.

Accomplishments

Accomplishments under the support of this grant include the further development and testing of radar data assimilation components to be used in the WRF 3DVAR system (Gao et al 2004a) and the application of the 3DVAR system for the initialization of a convective storm (Hu and Xue 2005; Hu et al. 2005a; Hu et al. 2005b), and the testing of radar data within the WRF-GSI 3DVAR system (Liu et al. 2005). The group also worked on improved forward operators for radar data, the comparisons of methods for calculating radar ray paths, and studied the sensitivity of ray path calculations to refractive index gradient and the climatology of severe index gradient that cause ray ducting (Gao et al. 2005a). In addition, a new method for simple-Doppler velocity retrieval is developed (Gao et al. 2005b). Additional work is done in developing a system for assimilating radar and other data based on the ensemble Kalman filter technique (Tong and Xue 2005; Xue et al. 2005).

In spring of 2005, CAPS participated in the SPC Spring Program and ran the WRF model at 2 km resolution over the eastern 2/3 of the Continental US in real time, one time a day, to produce 30 hour forecasts over a 40 day period. The results are compared WRF-ARW produced by NCAR and WRF-NMM forecasts produced by NCEP at about 4 km resolutions. The following figure presents an example of 24 hour 2 km WRF forecast reflectivity field valid at 00Z 30 June 2005, which compares favorably with the observed reflectivity.

This project is ongoing.

Publications

Gao, J., K. Brewster, and M. Xue, 2005a: A comparison of the radar ray path equations and approximations for use in radar data assimilation. *Adv. Atmos. Sci.*, accepted.

Gao, J., M. Xue, S. Y. Lee, K. K. Droegemeier, and A. Shapiro, 2005b: A three-dimensional variational method for velocity retrievals from single-Doppler radar observations on supercell storms. *Meteor. Atmos. Phys.*, accepted.

Hu, M. and M. Xue, 2005: Impact of configurations of rapid intermittent assimilation of WSR-88D radar data for the 8 May 2003 Oklahoma City tornadic thunderstorm case. *Mon. Wea. Rev.*, to be submitted.

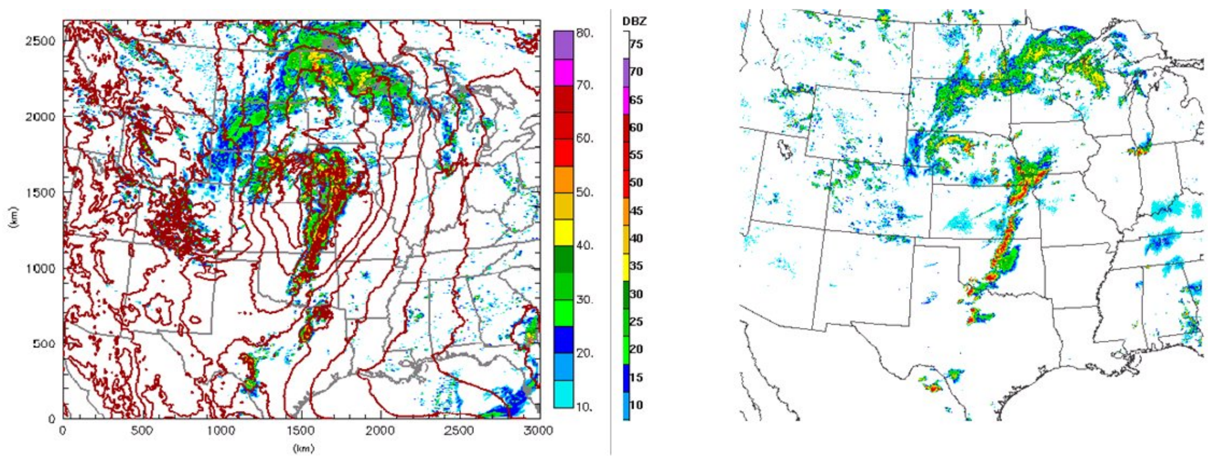
Hu, M., M. Xue, and K. Brewster, 2005a: 3DVAR and Cloud analysis with WSR-88D Level-II Data for the Prediction of Fort Worth Tornadic Thunderstorms. Part I: Cloud analysis and its impact. *Mon. Wea. Rev.*, accepted.

Hu, M., M. Xue, J. Gao, and K. Brewster, 2005b: 3DVAR and Cloud analysis with WSR-88D Level-II Data for the Prediction of Fort Worth Tornadic Thunderstorms. Part II: Impact of radial velocity analysis via 3DVAR. *Mon. Wea. Rev.*, accepted.

Liu, S., M. Xue, J. Gao, and D. Parrish, 2005: Analysis and impact of super-obbed Doppler radial velocity in the NCEP grid-point statistical interpolation (GSI) analysis system. Extended Abstract, 17th Conf. Numerical Weather Prediction, Washington DC, Amer. Meteor. Soc., 13A.4.

Tong, M. and M. Xue, 2005: Ensemble Kalman filter assimilation of Doppler radar data with a compressible nonhydrostatic model: OSS Experiments. *Mon. Wea. Rev.*, **133**, 1789-1807.

Xue, M., M. Tong, and K. K. Droegemeier, 2005: An OSSE framework based on the ensemble square-root Kalman filter for evaluating impact of data from radar networks on thunderstorm analysis and forecast. *J. Atmos. Ocean Technol.*, accepted.



Comparison of the 2005 Spring Project 24-hour real time forecast composite reflectivity and mean sea level pressure (left panel) valid at 00Z June 5, 2005 and observed radar reflectivity (right panel).

Climatic Effects of/Controls on Mesoscale Processes

Evidence of Tropospheric Biennial Oscillation and Influence of the Indian Ocean over the Horn of Africa

Lamb (primary – CIMMS at OU)**, Leslie, Segele**

NOAA Strategic Goal 2 *(Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond)*

Funding Agency: CIMMS

Objectives

Examine the biennial variability in the Horn of Africa rainfall associated with the tropospheric biennial oscillation; identify the effects of Indian Ocean on the summer monsoon over the Horn of Africa; examine the intraseasonal and interannual variability of regional circulations using regional climate model.

Accomplishments

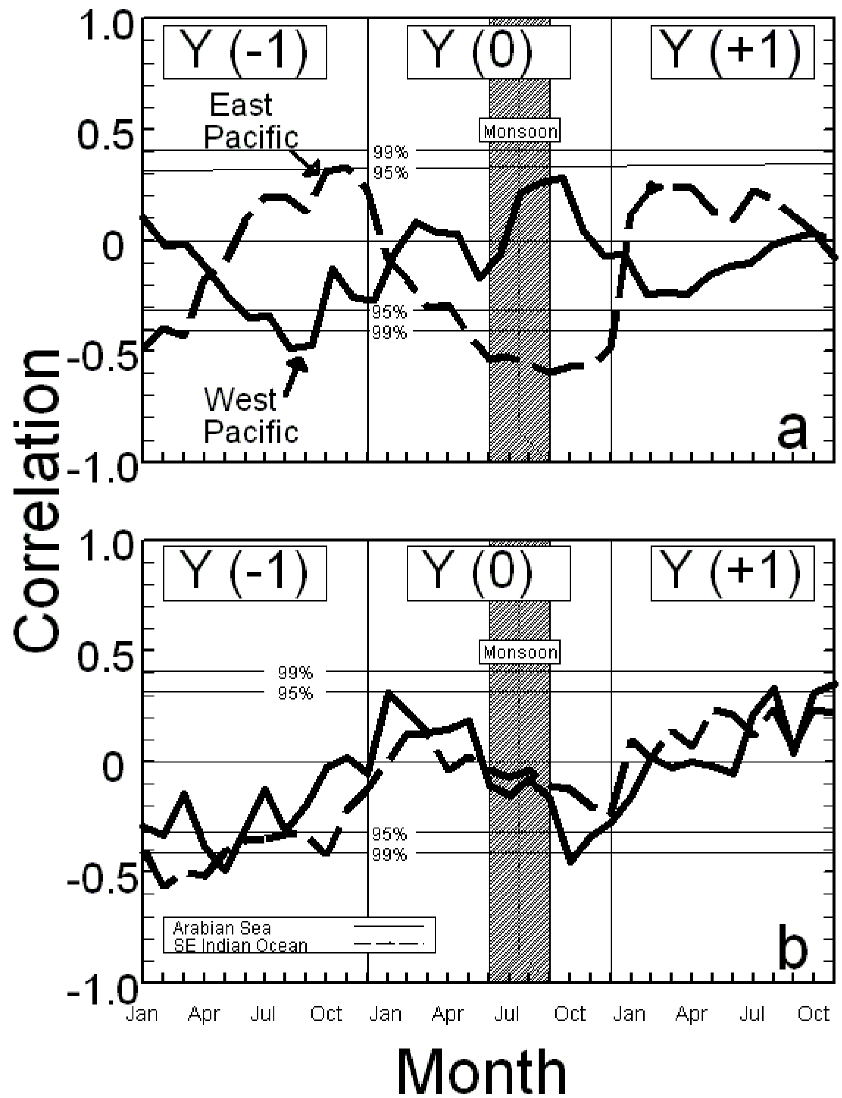
The Indian monsoon rainfall exhibits strong biennial variability associated with the tropospheric biennial oscillation (TBO) and inversely strongly correlates with the El Niño-Southern Oscillation (ENSO) phenomenon. In recent decades, the inverse relationship between Indian monsoon rainfall and ENSO has considerably changed. In particular, many studies report a weakening in the ENSO-monsoon relationship after the 1976-77 climate shift. In addition, significant changes in the amplitude, spatial structure and temporal evolution of El Niño events are observed over the Indian Ocean after the 1976-77 climate shift.

To examine if such characteristics of the Asian monsoon extend to the Horn of Africa, lagged correlations are computed between All Ethiopian summer rainfall (AESR) and ENSO for 1961-99 (see panel a of figure below). The biennial variability of AESR show a specific TBO pattern of distinct seasonal sequence as evidenced in All Indian summer rainfall biennial patterns, but with a slight shift in the timings of peak correlations. In addition, lagged correlations between AESR and SSTs over the Indian Ocean reveal a strong biennial variability (see panel b of figure below). However, the correlation patterns differ significantly from that observed for Indian monsoon rainfall in the year proceeding the reference year. Finally, the Indian Ocean exerts stronger influence on the Horn of Africa after the post 1976-77 climate shift, during which the correlation between AESR and SST over the Arabian Sea jumps to 0.72. Currently, The Abdus Salam International Center for Theoretical Physics (ICTP) REGional Climate Model version 3 (RegCM3) is being used to examine the dynamical influence of the Indian Ocean and gain insight into the physical processes involved in the interannual rainfall variability over the Horn of Africa.

This project has been completed.

Publications

Segele, Z.T., and P. J. Lamb, 2005: Characterization and variability of Kiremt rainy season over Ethiopia. *Meteorol. Atmos. Phys.*, **89**,153-180.



Lagged correlations between standardized Ethiopian June-September rainfall anomaly and the SST anomaly in the western Pacific Ocean (0°-8°N, 130°-150°E, solid curve) and the eastern Pacific Ocean (0°-8°N, 170°-150°W, dashed curve). Y(-1) and Y(+1) refer to the year before and after reference year (Y0). b) Same as in a) but for the Arabian Sea (17°-23°N, 63°-69°E, solid curve) and southeastern Indian Ocean (5°N-45°S, 90°-122°E, dashed curve).

Influence of Intertropical Front on Rainfall Variability in West Africa Sahelian Countries

Issa LeLe, Lamb (primary – CIMMS at OU)

NOAA Strategic Goal 2 *(Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond)*

Funding Agency: CIMMS and CIMMS Task III – NWS International Activities Office

Objectives

Examine the intraseasonal and interannual variability of the Intertropical Front (ITF), also called Intertropical Discontinuity (ITD), and total rainfall over West Africa Sahelian countries during 1974-2003.

Accomplishments

This study examines the intraseasonal and interannual variability of the Intertropical Front (ITF), also called Intertropical Discontinuity (ITD), and total rainfall over West Africa Sahelian countries during 1974-2003. The analysis is based on three data sets -- daily dew point temperatures, daily rainfall, and NCEP/NCAR reanalyses. Dew point temperatures were computed from observed daily minimum temperature and maximum relative humidity for synoptic stations in the Sahel (10^o-25^oN, 12^oW-24^oE). Observed daily raingauge data were used to study the performance of the monsoon in association with the ITF positions. Global circulation features associated with the advance and retreat of the ITF and the occurrence of extreme conditions in the area were explored using NCEP/NCAR reanalyses data. Preliminary results suggest that delayed northward excursion of the ITF does not necessary imply drought conditions in the Sahel. Composite analysis of wet and dry episodes, in fact, suggests that a northward displacement of the ITF may account for wetter conditions, but that droughts years are likely to be caused by changes in convergence strength during the rainy season regardless of the ITF position. The depth of the monsoon westerlies seems to be the primary factor controlling the strength of the convection that produces rainfall in the region.

This project is ongoing.

Investigation of Synoptic and Mesoscale Meteorological Processes Associated with Hazardous Weather – *Pan American Climate Studies Sounding Network (PACS-SONET)*

Douglas (primary – NSSL)**, Galvez, Mejia, Murillo, Orozco**

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: CIMMS Task II – NSSL Project 6

Objectives

Operate approximately 20 pilot balloon stations in countries ranging from Mexico to Paraguay, the essential goal being to describe the major circulation features of the lower-mid troposphere over the its domain.

Accomplishments

With less stations than expected (due to Peru's temporary withdrawal), we collected about 400 observations per month in average during the period. Increased participation in the project is expected from the Peruvian weather service and also from the Colombian Air Force, after a visit with them that included talks and training sessions to the observer staff.

A short experiment was carried out in Venezuela to study the structure of the low level jet observed during the last 3 years from PACS-SONET measurements in the Venezuelan llanos (the very flat region along the drainage of the Orinoco River).

This project is ongoing.

Publications

Killeen, T., M. Douglas, T. Consiglio, P. M. Jørgensen, and J. F. Mejia, 2005: Understanding the precipitation patterns on the eastern slope of the tropical Andes in the context of biodiversity conservation. *Global Ecology and Biogeography*, submitted.

Peña, M., and M. W. Douglas, 2002: Characteristics of wet and dry spells over the Pacific side of Central America during the rainy season. *Mon. Wea. Rev.,* **130**, 3054-3073.

Douglas M.W., J. M. Galvez, J. F. Mejia, C. Brown, R. Orozco, and C. Watts, 2005: Seasonal evolution of the sea-land breeze circulation and its role in the precipitation climatology of northwestern Mexico. CD-ROM, *Sixth Conf. on Coastal Atmospheric and Oceanic Prediction and Processes*, San Diego, CA, Amer. Meteor. Soc., 3.7.

Galvez, Jose M., R. Orozco and M. W. Douglas, 2005: Measuring and monitoring the mesoclimate of tropical locations. Field observations from the South American altiplano during the SALLJEX. *13th Symp. on Meteorological Observations and Instrumentation*, Savannah, GA, 6.2, PDF.

Murillo, Javier, M. W. Douglas, J. M. Galvez, J. F. Mejia, R. Orozco, and C. Brown, 2005: Quality control of pilot balloon data for climate monitoring. *13th Symp. on Meteorological Observations and Instrumentation*, Savannah, GA, JP 1.30, PDF.

Douglas, Michael W., J. Murillo, and J. F. Mejia, 2005: Conducting short duration field programs to evaluate sounding site representativeness and potential climate monitoring biases – examining the low level jet over the Venezuelan Llanos during the 2005 dry season. *13th Symp. on Meteorological Observations and Instrumentation*, Savannah, GA, JP1.32.

Severe Weather Climatology via Reanalysis Soundings – Weather and Climate Assessment Initiative

Brooks (primary – NSSL), **Benson**

NOAA Strategic Goal 2 *(Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond)*

Funding Agency: UCAR

Objectives

Estimate the distribution of environments favorable for severe thunderstorms around the globe.

Accomplishments

Work has been conducted on describing the evolution of convective parameters in both the U.S. and Europe, with an aim to analyze globally environments favorable to severe storms.

This project is ongoing.

Publications

Brooks, H. E., A. R. Anderson, K. Riemann, I. Ebbers, and H. Flachs, 2005: Climatological aspects of convective parameters from the NCAR/NCEP reanalysis. *Atmos. Res.*, in press.

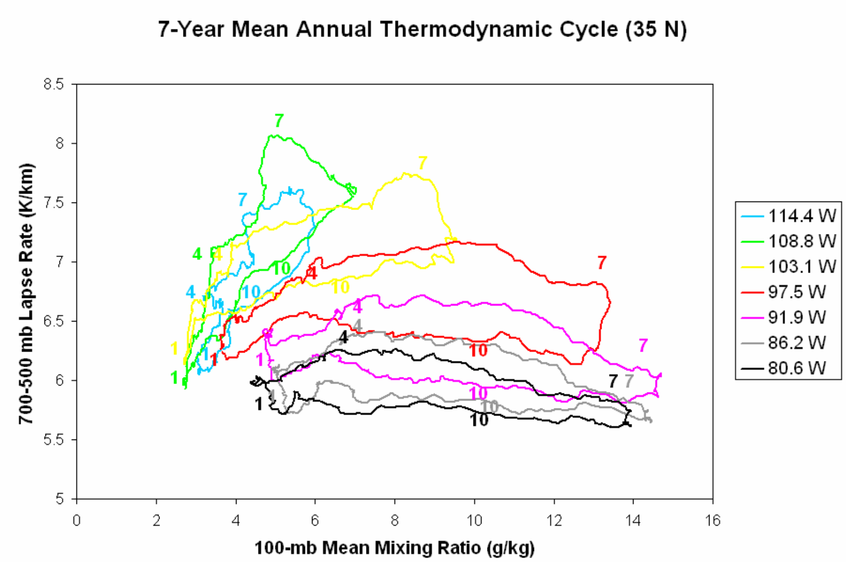
Brooks, H. E., 2004: Estimating the distribution of severe thunderstorms and their environments around the world. Preprints, *International Conf. on Storms*, Brisbane, Queensland, Australia.

Brooks, H. E., and A. R. Anderson, 2004: Climatological aspects of convective parameters from the NCAR/NCEP reanalysis. CD-ROM, *22nd Conf. on Severe Local Storms*, Hyannis, MA, Amer. Meteor. Soc.

Trapp, R. J., S. A. Tessendorf, E. S. Godfrey and H. E. Brooks, 2005: Tornadoes from Squall Lines and Bow Echoes. Part I: Climatological Distribution. *Wea. Forecasting*, **20**, 23–34.

Brooks, H. E., 2004: On the relationship of tornado path length and width to intensity. *Wea. Forecasting*, **19**, 310-319.

Brooks, H. E., 2004: Tornado warning performance in the past and future: A perspective from signal detection theory. *Bull. Amer. Meteor. Soc.*, **85**, 837-843.



Mean annual cycles of lowest 100-HPa mean mixing ratio and 700-500 hPa lapse rate at 35° N. Numbers indicate first day of month (1-January, 4-April, 7-July, 10-October).

Socioeconomic Impacts of Mesoscale Weather Systems and Regional Scale Climate Variations

Energy Indices

Timmer, Lamb (primary – CIMMS at OU)

NOAA Strategic Goal 2 *(Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond)*

Funding Agency: CIMMS Task III – NOAA OGP

Objectives

Understand the relationship between temperature and residential natural gas consumption in the U.S.

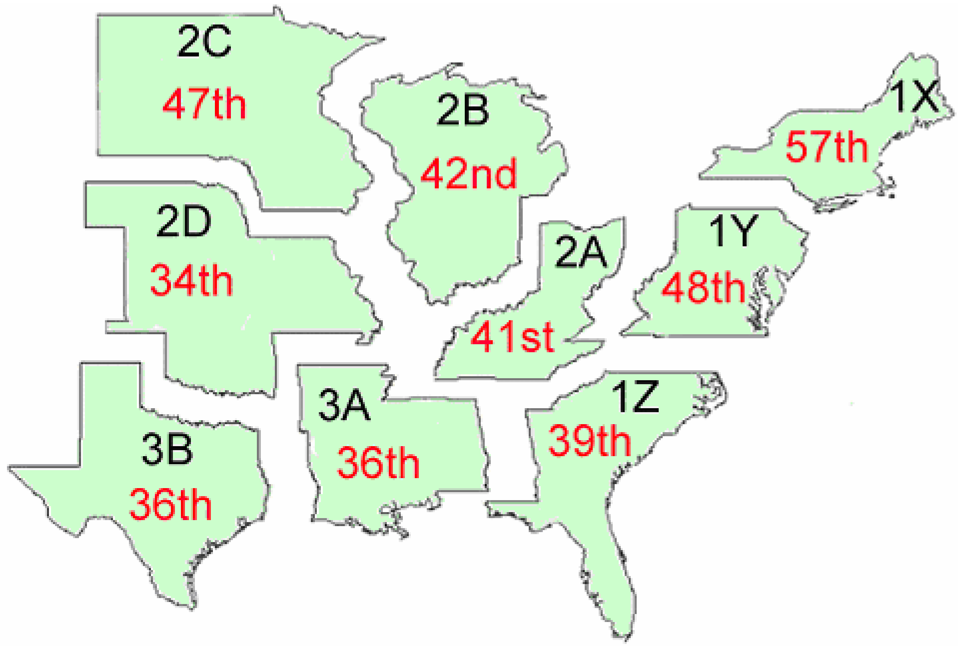
Accomplishments

Understanding of the relationship between temperature and residential natural gas consumption has become increasingly important since the deregulation of the natural gas industry in the mid 1980s. Monthly and seasonal natural gas price volatility has increased substantially since the restructuring of the natural gas market, and much of this price volatility can be attributed to changes in temperature-related residential natural gas demand. The emergence of futures and spot natural gas markets during the late 1980s further enhanced the importance of understanding the true relationship between temperature and residential natural gas consumption, since future and spot prices of natural gas are closely linked to weather-related demand. This study quantifies the relationship between U.S. regional winter temperature and residential natural gas demand through the development of two different types monthly and seasonal temperature-based indices designed to maximize their correlation with regional natural gas consumption.

The two types of natural gas consumption indices developed in this study are based on disparate methods of describing monthly and seasonal anomalous temperature: indices based on the totals of days below site-specific and monthly-specific temperature percentile thresholds ("days below percentile" or DBP indices), and indices based on quantities similar to heating degree days but with regionally varying reference temperatures ("heating degree day" or HDD indices). The monthly and seasonal DBP and HDD indices were derived for nine regions east of the Rocky Mountains for each winter season from 1949 to 2000, using 456 stations from the Richman-Lamb daily temperature dataset. State natural gas consumption contributions and state populations were used as weighting factors in developing the regional DBP and HDD indices.

Separate DBP and HDD indices were derived from daily maximum, minimum, and mean temperature data to determine which type of daily temperature data best correlates to the residential natural gas consumption of each of the nine regions considered. The indices based on daily maximum temperature have the highest correlations to residential natural gas consumption in regions with the coldest winter climates, while the indices based on daily mean temperature have the best index correlations in a majority of the remaining regions. The monthly and seasonal DBP and HDD indices of the regions representing the Ohio River Valley and the Great Lakes have the highest correlations to residential natural gas consumption, while the monthly and seasonal indices representing New England and the monthly indices representing the Gulf Coast states have relatively low index correlations. Index correlation values as high as .92 and .99 were achieved on the monthly and seasonal levels respectively, with HDD indices having the largest correlations on the monthly level, and DBP indices having the largest correlations on the seasonal level in a majority of the nine regions.

This project is ongoing.



Distribution of the mean optimum DBP base percentiles for the non-weighted DBP indices based on daily mean temperature. The mean percentiles are calculated by averaging the optimum percentiles for the monthly and seasonal DBP indices of three and four-month winters.

Tornado Warning Lead Time and Tornado Casualties

Sutter (primary – OU Dept. of Economics), Simmons, Schroeder

NOAA Strategic Goal 2 *(Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond)*

Funding Agency: CIMMS Task III – NSSL

Objectives

Explore how the issuing of a tornado warning and the lead time on a warning affects fatalities and injuries. Answer the question whether longer lead times save lives or not.

Accomplishments

We examine the impact of the installation of WSR-88D (Doppler) radars in the 1990s on the quality of tornado warnings and occurrence of tornado casualties. Our analysis employs a data set of tornadoes in the contiguous United States between 1986 and 1999. We use the date of WSR-88D radar installation in each National Weather Service Weather Forecast Office to divide our sample. Tornado warnings improved after installation of Doppler radar; the percentage of tornadoes warned for increased from 35% before WSR-88D installation to 60% after installation while the mean lead time on warnings increased from 5.3 minutes to 9.5 minutes and the false alarm ratio fell slightly. A regression analysis of tornado casualties, which controls for the characteristics of a tornado and its path, reveals that expected fatalities and expected injuries were 45% and 40% lower for tornadoes occurring after WSR-88D radar was installed in the NWS Weather Forecast Office. Our analysis also finds that expected casualties are significantly lower for tornadoes occurring during the day or evening than late at night throughout the sample, which provides indirect evidence of the life saving effects of tornado warnings. We will use the casualty models estimated in this work for an extension to estimate the number of lives and injuries which are being saved due to improvements in warning lead times between 1986 and 2002.

This project is ongoing.

Publications

Simmons, K. M., and D. Sutter, 2005: WSR-88D radar, tornado warnings, and tornado casualties. *Wea. Forecasting*, **20**, 301–310.
Simmons, K. M., and D. Sutter, 2005: Protection from Nature's fury: An analysis of fatalities and injuries from F5 tornadoes. *Natural Hazards Rev.*, **6(2)**, 82-87.
Simmons, K. M., and D. Sutter, 2004: Analysis of tornado casualties using the census tract tornado path dataset. CD-ROM, *22nd Conf. on Severe Local Storms*, Amer. Meteor. Soc., paper 3.B.5.

Multiscale Evolution and Predictability of a Warm Season Climate Anomaly in the U.S. Southern Great Plains

Portis (primary – CIMMS at OU)**, Leslie, Lamb**

NOAA Strategic Goal 2 *(Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond)*

Funding Agency: CIMMS

Objectives

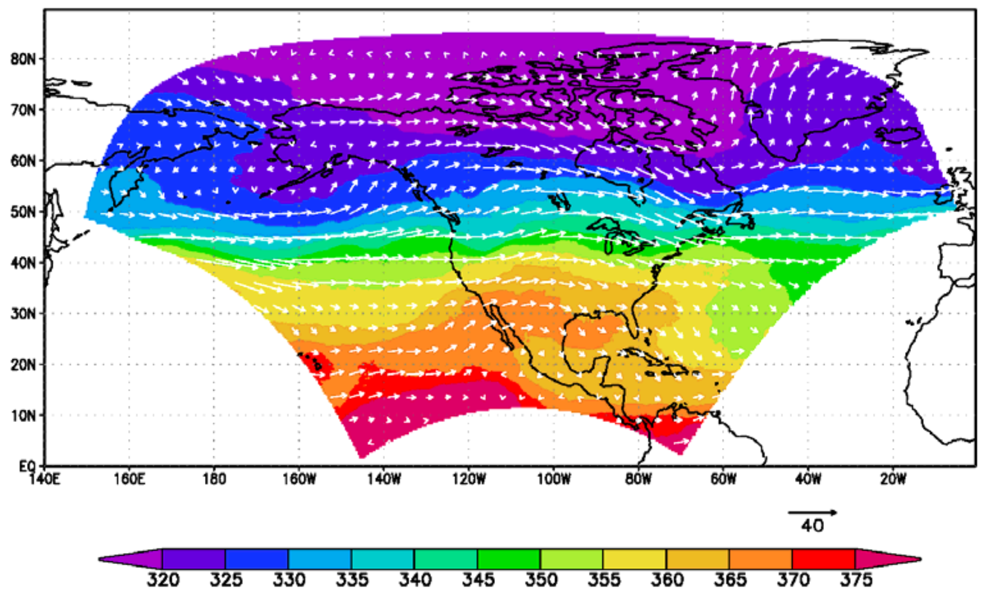
Explore the evolution and maintenance of the cool and wet anomaly over the Southern Great Plains in the summer of 2002. An underlying motivation is to ascertain the predictability of such a long term climate anomaly – it was hypothesized that its evolution involved a series of multi-scale events with possible non-linear interactions, thus making predictability difficult.

Accomplishments

In the previous fiscal year, Paul Nutter had concentrated on the maintenance of the cool anomaly. A key result of his research was the identification of an advection dipole in the temperature anomaly field that positively interacted with the long-term mean flow. This persistent dipole could be an important identifiable feature of long-lead predictions for recurring intraseasonal anomalies in the future.

This past fiscal year focused more on the evolution of the cool and wet anomaly whose genesis was a stalled cut-off low over Texas that brought flooding rains during the first week of July. This cut-off low was in an ideal location for maximizing moisture flux into Texas. From our analysis, four key factors have emerged in the evolution of the flood and the genesis of the wet and cool anomaly over the Southern Great Plains in the summer of 2002: (1) the frequent generation of upper level potential vorticity anomalies that formed and maintained the cut-off Texas low. The persistent location of their generation suggests linkage to anomalous boundary conditions such as snow cover, ice extent and SST; (2) poleward migration of the jet flow. This enabled the upper level potential vorticity anomalies in the eastern Atlantic to retrograde westward into the southern United States. This poleward migration of the jet is probably due to the anomalously intense low over the western Arctic ocean; (3) ridging over the western United States due to a long-lived drought in that region. This western ridge prevented the upper level cut-off low from retrograding farther westward. The stalled location of the cut-off low maximized the availability of moisture from the Gulf into the region; (4) local Topography in Texas. The Balcones Escarpment in the south Texas hill country has been identified as a reintensification mechanism for storms in that region. There is evidence of the first three of these factors in the accompanying figure of the potential temperature and winds on the tropopause for June 2002. Tropopause winds are cyclonic around cold regions of potential temperature. The figure indicates two cold regions where the generation of upper level potential vorticity anomalies are favored northeastern Canada and south of Alaska. The poleward jet and ridge over the western United States are also persistent features that are reflected at the tropopause level. Tropopause winds that have a large horizontal extent are likely to extend down to the surface.

This project is ongoing.



Tropopause winds and potential temperatures for June 2002. Data from the National Centers Environment Prediction (NCEP) North American Regional Reanalysis (NARR) was used to construct this figure.

Extreme Temperature Events in North America East of the Rocky Mountains: A Summer Climate Analysis

Rogers, Lamb (primary – CIMMS at OU)

NOAA Strategic Goal 2 *(Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond)*

Funding Agency: Williams Companies

Objectives

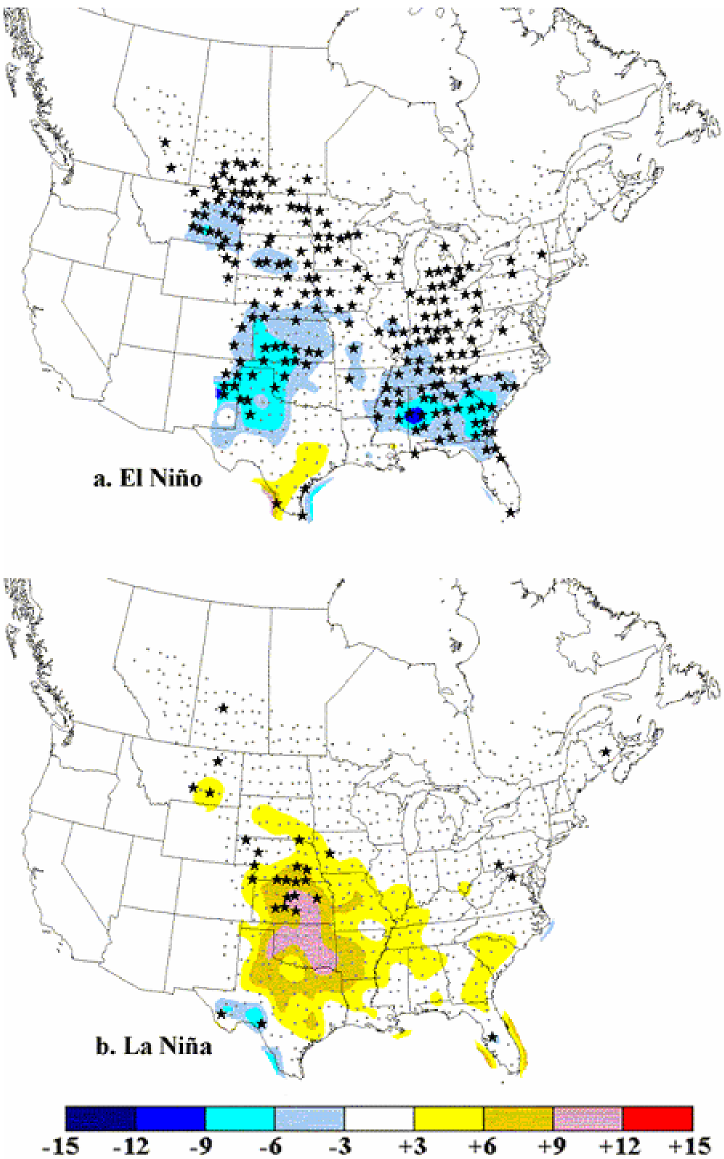
Use daily temperature exceedence thresholds to evaluate the societal impacts of summer extremes.

Accomplishments

While extensive study has been performed on the teleconnections between El Niño/La Niña and North American temperature and precipitation, the majority of that research has focused on seasonal or monthly average anomaly patterns. Unlike these previous studies, daily maximum temperature is necessary to evaluate the societal impacts of extreme summer temperatures. The use here of daily temperature exceedence thresholds adds a new perspective on the relationships between El Niño/La Niña and North American temperature.

El Niño and La Niña events were defined for summers from 1949-2000 using monthly averaged sea-surface temperature data for the equatorial Pacific Niño 3.4 region to define whole summers as El Niño, La Niña, and neutral. These summers were analyzed individually, as well as in El Niño and La Niña composites. North American daily maximum temperature data with approximately 1° latitude-longitude resolution were used to identify relationships between El Niño/La Niña events and the summer frequency of 90°F, 95°F, and 100°F days through North America east of the Rocky Mountains. Average temperature composite anomaly patterns were generated to assure consistency with other recent analyses.

The strongest relationships between daily maximum temperature and El Niño and La Niña composites were found through the Central and Southern Plains, with an increase relative to the climatological mean in the number of 95°F and 100°F days (9-12 and 6-9 more days per summer, respectively) during La Niña, and a decrease (6-9 fewer days per summer) during El Niño summers. However, investigation into the constituent years of the El Niño and La Niña composites showed that El Niño threshold exceedence anomalies are generally more consistent and statistically significant than their La Niña counterparts. Additionally, the constituent years displayed substantial interannual variability that might limit the potential predictive value of the composite analyses.



Mean summer season (June-September) departures of the number of days in which the maximum temperature reached or exceeded 95˚F (35.0˚C) for sets of (a) El Niño and (b) La Niña years from the average 1949-2000 summer. Dots indicate primary stations in the Richman-Lamb data set used here. A star is plotted at stations where the composite value is significantly different from zero at 90% level, according to a t-test procedure.

Doppler Weather Radar Research and Development

Quantitative Precipitation Estimation and Segregation Using Multiple Sensors – *Improved Quantitative Precipitation Estimation*

Arthur, Clarke, Cox, Fang, Gourley (primary – CIMMS at NSSL)**, Langston, Wang, Xia, J. Zhang, Farmer**

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: CIMMS Task II – NSSL Project 2

Objectives

Address the encompassing need to monitor the nation's freshwater resources. A critical component to this effort involves the detection and quantification of surface rainfall and snowfall prior to its transition to stream flow, surface water storage, atmospheric water vapor, and ground water recharge. Due to the high spatial variability of precipitation, it becomes necessary to incorporate sources of information from remote sensing platforms such as radar and satellite with in situ instruments such as rain gauges. Several approaches to improved quantitative precipitation estimation (QPE) have been explored using the latest technologies in polarization diversity, reflectivity data from radars operating at C-band frequencies, multi-channel satellite retrievals, and blending of the remotely-sensed data with rain gauges. The accuracy, spatial coverage, and resolution of these QPE fields are directly related to the precision one can expect from hydrologic model forecasts of stream flow. In addition, the timeliness of these forecasts can be improved using extrapolation methods of QPE fields for short time periods in which numerical model forecasts have limited skill. While several of these studies have been performed over small domains, algorithm development has proceeded with a national implementation in mind.

Accomplishments

Polarization diversity offers the potential to improve QPE fields due to traditional reflectivity-based methods being sensitive to drop size distribution variability, contamination from hail, melting hydrometeors and non-hydrometeorological scatterers such as biological targets and ground clutter. The availability of rainfall datasets from the JPOLE experiment were found to be incomplete for adequate hydrologic simulation spanning multiple hours and even days. Efforts have thus been focused on the improvement of data quality and identification of hail and the bright band through the use of polarimetric variables. Recent studies (Gourley et al. 2005a) have shown that ground clutter and clear air echoes can be almost entirely eliminated using a fuzzy logic approach. The co-polar, cross-correlation coefficient and texture of differential propagation phase are extremely effective in identifying and thus removing non-hydrometeorological scatterers from QPE fields, thus dramatically improving their quality.

Prior research has pointed at inadequacies of the NEXRAD radar network coverage over the Intermountain West especially for cool season precipitation. Radars operating at C- and X-band frequencies are more affordable than NEXRAD radars and offer the potential to fill in gaps in the NEXRAD coverage. In addition, freshwater monitoring can be improved in the northern US (e.g., Great Lakes region) through the incorporation of Canadian C-band radar data. These radars, however, suffer from attenuation of the microwave energy in moderate and heavy rainfall. Research has been conducted at C-band using the MeteoFrance operational radar to correct for attenuation of reflectivity and differential reflectivity. Radar-radar comparisons have shown that this technique successfully removes biases due to attenuation (Gourley et al. 2000b). This algorithm may be easily transported to newly deployed C-band radars for improving the range at which precipitation can be detected and estimated.

Another approach to dealing with the inadequacies of the NEXRAD radar coverage is the incorporation of information from satellite data. Satellite data do not offer the time and spatial resolution available with radar data. Moreover, satellite-born sensors passively receive radiation from clouds, which is indirectly related to precipitation intensities. Nonetheless, this information is believed to be complementary to radar data where beam blockages are severe and the intensity of the rainfall is too light to be detected by radar. A study has been carried out to explore the usefulness of multiple satellite channels to address these problems in radar-based QPE. A rainfall event was studied in Oklahoma where the gauge network is considered dense and the NEXRAD coverage is sufficient. Warm rain processes were producing rainfall observations at rain gauges that were below the detection capabilities of radar. This situation is believed to be a common occurrence in the Intermountain West where the gauge network is much sparser. It was discovered that the satellite-detected radiance at 3.9 microns in warm clouds produced a rainfall signal that was below the signal-to-noise threshold in radar. This initial study highlights the prospects of incorporating "nontraditional" satellite channels for improving the detection of rainfall. Another use of satellite data is to improve the quality of radar reflectivity images. The differences between cloud-top temperatures from satellite and RUC-analyzed surface temperatures are being computed over the US every 15 min. If the temperature difference is small, then conditions are believed to be devoid of clouds and contaminants on radar reflectivity images are removed. A second, perhaps more robust mask is created on an hourly basis using the GOES sounder data.

Rain gauges provide valuable information regarding measured rainfall intensities at point locations. The integration of these data into radar-based QPE products is challenging due to their large differences in spatial scales. Rain gauge data that report in real-time are collected and converted to a common format over the entire US. These reports serve two purposes. First, they are integrated in the software in order to evaluate radar-based algorithms on an automated basis. Second, they may now be used to adjust multisensor QPE fields. The gauge weighting parameters have been optimized for use over the Lower Colorado River Authority region near Austin, TX (Barrere et al. 2005) and in Italy. Gridded gauge-only fields are now being produced in real-time. In addition, these fields are used to adjust radar-based QPEs using a mean field bias and a bias that has spatial variability. The former field maintains the spatial details present in the raw radar images, while the latter tends to smooth spatial details while maintaining agreement with collocated gauge reports. It was discovered in Gourley and Vieux (2005a) that spatial variability captured by radar data was needed for accurate hydrologic simulation.

A multi-scale storm-tracking algorithm has been adapted and tested using several precipitation cases. This algorithm uses gridded fields such as observed radar reflectivity and QPE maps to provide forecasts up to 3 hours in the future. The method uses consecutive images in order to estimate storm motion vectors at different scales. These vectors are then used to extrapolate the fields. Forecast products have been evaluated using several precipitation events including 3 typhoons and a tornadic supercell. The forecasts performed well for the typhoon case given the relatively slow movement and large area of the precipitation. The skill scores are higher than 0.6 for most of the forecasts, including the 3-h forecasts. The results for the tornado case, however, are not as good due to the isolated and scattered nature of the reflectivity images. In summary, skill scores improve as the storms become organized over larger scales.

A natural progression from precipitation monitoring and prediction is to forecast stream flow once the rainfall reaches the surface and becomes the primary forcing to hydrologic models. Traditionally, hydrologic models have relied on sparse rain gauge measurements to supply rainfall fields over large domains. The next generation of hydrologic models employ spatially distributed fields of soil characteristics, terrain slopes, land use, and precipitation. Gourley and Vieux (2005a) examined the sensitivity of stream flow forecasts from a distributed system to differing QPE inputs. It was discovered that the inclusion of satellite data as well as mean field bias adjustments from rain gauges improved hydrologic forecasts. The WISH QPE fields have subsequently been coupled to the National Weather Service's Distributed Hydrologic Modeling System. Moreover, these hydrologic forecasts have now been linked to a channel routing model. System coupling provides the capability to monitor rainfall and forecast flood-producing stream flows in channels.

This project is ongoing.

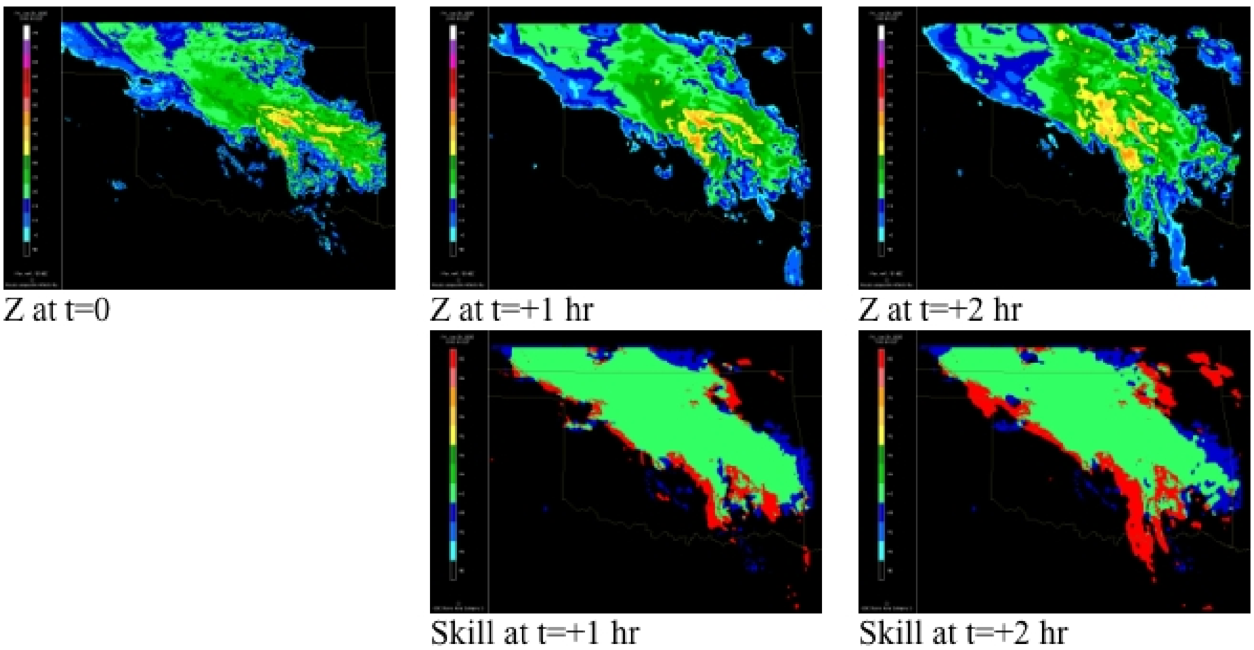
Publications

Barrere, C.A., M.D. Eilts, and B. Clarke, 2005: Hydrometeorological decision support system for the Lower Colorado River Authority. CD-ROM, *32nd Conf. on Radar Meteorology*, Albuquerque, NM, Amer. Meteor. Soc.

Gourley, J.J. and N. Dotzek, 2004: The effects of vertical air motions on radar estimates of rainfall. ERAD Publ. Ser. 2.

Gourley, J.J., R. A. Maddox, and B.M. Clarke, 2004: A multisensor approach to partitioning convective from stratiform echoes. ERAD Publ. Ser. 2.

Gourley, J.J. and B.E. Vieux, 2005a: Evaluating the accuracy of quantitative precipitation estimates from a hydrologic modeling perspective. *J. Hydrometeor.*, **6**, 115-133.
Gourley, J.J. and B.E. Vieux, 2005b: A method for identifying sources of model uncertainty in rainfall-runoff simulations, *J. Hydrol.*, submitted.
Gourley, J. J., P. Tabary, and J. Parent du Chatelet, 2005a: Classification of hydrometeors and non-hydrometeors using polarimetric C-band radar. CD-ROM, *32nd Conf. on Radar Meteorology*. Albuquerque, NM, Amer. Meteor. Soc.
Gourley, J. J., P. Tabary, and J. Parent du Chatelet, 2005b: A new polarimetric method for correcting the effects of attenuation at C-band. CD-ROM, *32nd Conf. on Radar Meteorology*. Albuquerque, NM, Amer. Meteor. Soc.
Gourley, J. J., and A. J. Illingworth, 2005: Calibration of absolute reflectivity at C-band using redundancy of the polarization parameters in rain. CD-ROM, *32nd Conf. on Radar Meteorology*, Albuquerque, NM, Amer. Meteor. Soc.
Langston, C., and J. Zhang, 2004: An automated algorithm for radar beam occultation. CD-ROM, *11th Conf. on Aviation, Range, and Aerospace Meteorology*. Amer. Meteor. Soc. paper 5.16.
Zhang, J., K. Howard, and J.J. Gourley, 2005: Constructing three-dimensional multiple radar reflectivity mosaics: examples of convective storms and stratiform rain echoes. *J. Atmos. Ocean. Technol.*, **22**, 30-42.
Zhang, J., S. Wang, and B. Clarke, 2004: WSR-88D reflectivity quality control using horizontal and vertical reflectivity structure. CD-ROM, *11th Conf. on Aviation, Range, and Aerospace Meteorology*, Amer. Meteor. Soc. Hyannis, MA. paper 5.4.
Zhang, J., and S. Wang, 2004: An automated 2-D multi-pass velocity dealiasing scheme. CD-ROM, *11th Conf. on Aviation, Range, and Aerospace Meteorology,* Amer. Meteor. Soc. Hyannis, MA. paper 5.5.



Images of forecast reflectivity using the multi-scale storm-tracking algorithm. The first row shows an observed reflectivity image and its forecast at 1 and 2 hours. The second row shows the skill scores. Green colors indicate areal agreement, red represents overforecasts (false alarms), and blue represents areas that were underforecast (misses).

Quantitative Precipitation Estimation and Segregation using Multiple Sensors – *National Mosaic and Multi-Sensor QPE (NMQ) Enhancement and Improvement*

J. Zhang (primary – CIMMS at NSSL)**, Langston, Wang, Xia**, **Clarke, Fang**

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: CIMMS Task II – NSSL Project 2

Objectives
Provide seamless CONUS 3-D radar reflectivity mosaic that has high spatial resolution (1km x 1km x 250m) and rapid update cycle (every 5 min) for severe weather applications and for meso-scale numerical weather model data assimilation; provide accurate CONUS precipitation estimates over a high-

resolution (1km x 1km) grid with a rapid update cycle (every 5min) for flash floods and floods warnings and for water resource management.

Accomplishments

The national 3-D radar reflectivity mosaic system has been enhanced and updated. The enhancements include: 1) new components in reflectivity quality control which include reflectivity adjustment for partially blocked beams, radial gap-filling, seasonal adaptive parameters for vertical reflectivity gradient algorithm, and clutter removal based on GOES satellite sounder data, and 2) integration of real-time level-3 data from WSR-88D radars that do not transmit level-2 data. The additional components in reflectivity quality control were implemented to further remove clutter echoes while retaining the integrity of precipitation systems. Ingesting of WSR-88D level-3 data improved radar coverage at the lower levels of the 3D mosaic grid especially in regions encompassed by the Department of Defense WSR-88D radars.

An experimental adaptive radar mosaic system has been developed to further improve the computational efficiency of the national 3D mosaic. Within the new system, data from individual radars are remapped onto a 3-D Single Radar Cartesian (SRC) grid. Each SRC grid is centered at a CONUS grid cell closest to the radar site and has the same spatial resolution and vertical levels as the 3D CONUS mosaic grid. As a result, the SRC grids are fully aligned with the 3D CONUS grid (i.e., each SRC grid cell is overlapped with a CONUS grid cell). When mosaicing multiple SRC grids, a simple distance weighted mean is applied at each grid cell with multiple radar coverage. With the new NMQ system, each radar volume scan is only processed once in the SRC grid. Thus the computational efficiency is greatly improved allowing for more frequent updates. The SRC grid also allows flexibility in spatial resolution and integration of data from different type of radars.

A suite of experimental precipitation products has been generated on the NMQ grid. There are 5 different QPE algorithms: 1) radar only, 2) satellite only, 3) radar and satellite or “multi-sensor”, 4) gauge bias adjusted radar QPE, 5) gauge bias adjusted multi-sensor QPE. Each algorithm generates a set of products in real-time that include precipitation rate (every 5min), 1- and 3-h accumulations (every 5 min), 6- and 24-h accumulations (every hour), and 72-h accumulation (daily). The products (without gauge bias adjustment) are evaluated using real-time gauge observations. Figure 1 shows example NMQ products.

This project is ongoing.

Publications

Zhang, J., K. Howard, and J.J. Gourley, 2005: Constructing three-dimensional multiple radar reflectivity mosaics: examples of convective storms and stratiform rain echoes. *J. Atmos. Ocean. Technol.*, **22**, 30-42.

Zhang, J., K. Howard, W. Xia, C. Langston, S. Wang, and Y. Qin, 2004: Three- and Four-Dimensional High-Resolution National Radar Mosaic. ERAD Publ. Ser. 2. 105-108.

Zhang, J., K. Howard, W. Xia, C. Langston, S. Wang, and Y. Qin, 2004a: Three-dimensional high-resolution national radar mosaic. CD-ROM, *11th Conf. on Aviation, Range, and Aerospace Meteorology*. Amer. Meteor. Soc. Hyannis, MA. paper 3.5.

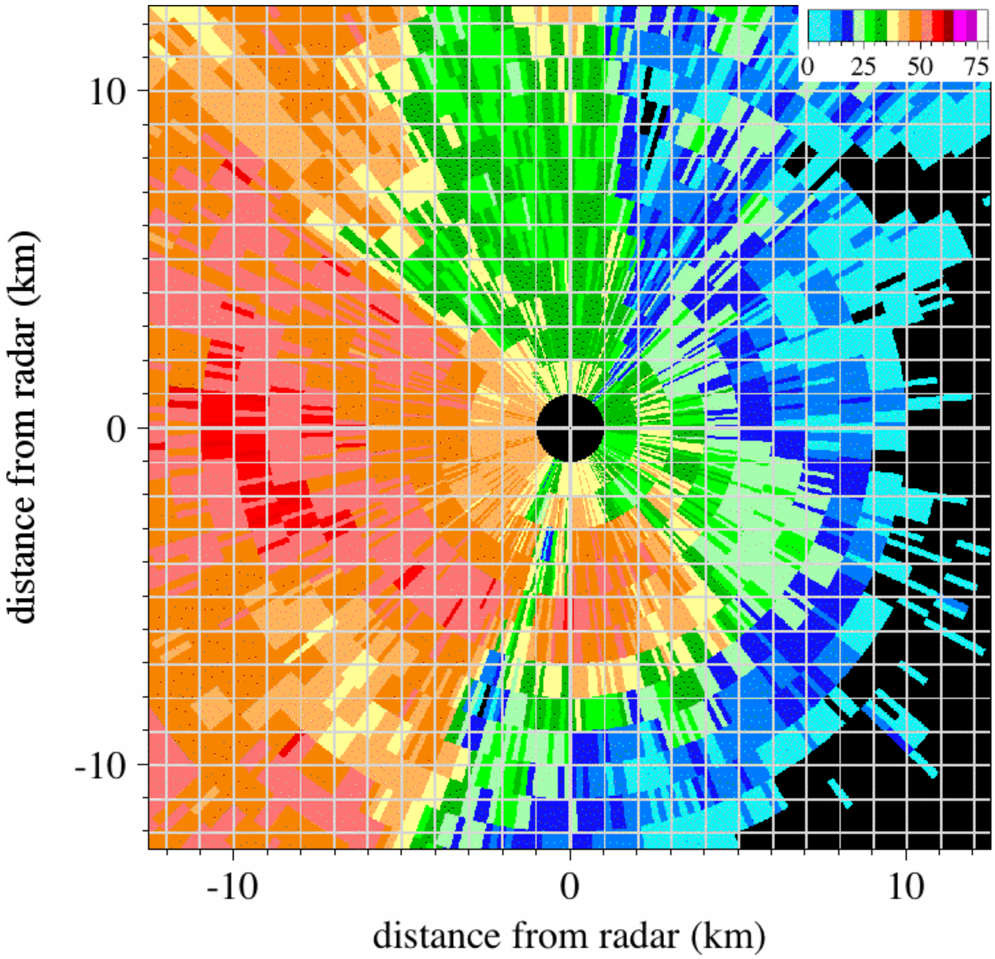
Zhang, J., S. Wang, and B. Clarke, 2004b: WSR-88D reflectivity quality control using horizontal and vertical reflectivity structure. CD-ROM, *11th Conf. on Aviation, Range, and Aerospace Meteorology*. Amer. Meteor. Soc. Hyannis, MA. paper 5.4.

Zhang, J., and S. Wang, 2004: An automated 2-D multi-pass velocity dealiasing scheme. CD-ROM, *11th Conf. on Aviation, Range, and Aerospace Meteorology*. Amer. Meteor. Soc. Hyannis, MA. paper 5.5.

Langston, C., J. Zhang, and K. Howard, 2004: Four-dimensional dynamic radar mosaic. CD-ROM, *11th Conf. on Aviation, Range, and Aerospace Meteorology*. Amer. Meteor. Soc. Hyannis, MA. paper 5.11.

Langston, C., and J. Zhang, 2004: An automated algorithm for radar beam occultation. CD-ROM, *11th Conf. on Aviation, Range, and Aerospace Meteorology*. Amer. Meteor. Soc. Hyannis, MA. paper 5.16.

Seo, D. J., C. R. Kondragunta, K. Howard, S. V. Vasiloff, and J. Zhang, 2005: The national mosaic and multisensor QPE (NMQ) project-status and plans for a community testbed for high-resolution multisensor quantitative precipitation estimation (QPE) over the United States. CD-ROM, *19th Conf. on Hydrology*, Amer. Meteor. Soc., San Diego, CA, paper 1.3.



Example NMQ 24 hour precipitation accumulation fields and the comparison with gauge observations: a) the 24-h radar-only precipitation accumulation over the CONUS domain; b) a zooming-in view over the north-central US region; c) NMQ radar-only 24-h rainfall accumulation field comparing with gauge observations. Here each dot represents a gauge station, the size of the dots represent radar rainfall amount, the color of the dots represent the bias (ratio) of radar based rainfall estimate over the gauge observation; d) a scatter plot of radar-only 24-h rainfall accumulation versus gauge observations; e) and f) time series of hourly rainfall accumulations from gauge observations and from radar-only and multi-sensor precipitation estimations..

Severe Weather Warning Research and Application Development – *VCPExplorer*

Manross (primary – CIMMS at NSSL), **Smith**

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: CIMMS Task II – NSSL Project 3

Objectives

Develop an instructional tool to allow the user to qualitatively understand radar scanning characteristics and their effects on data quality.

Accomplishments

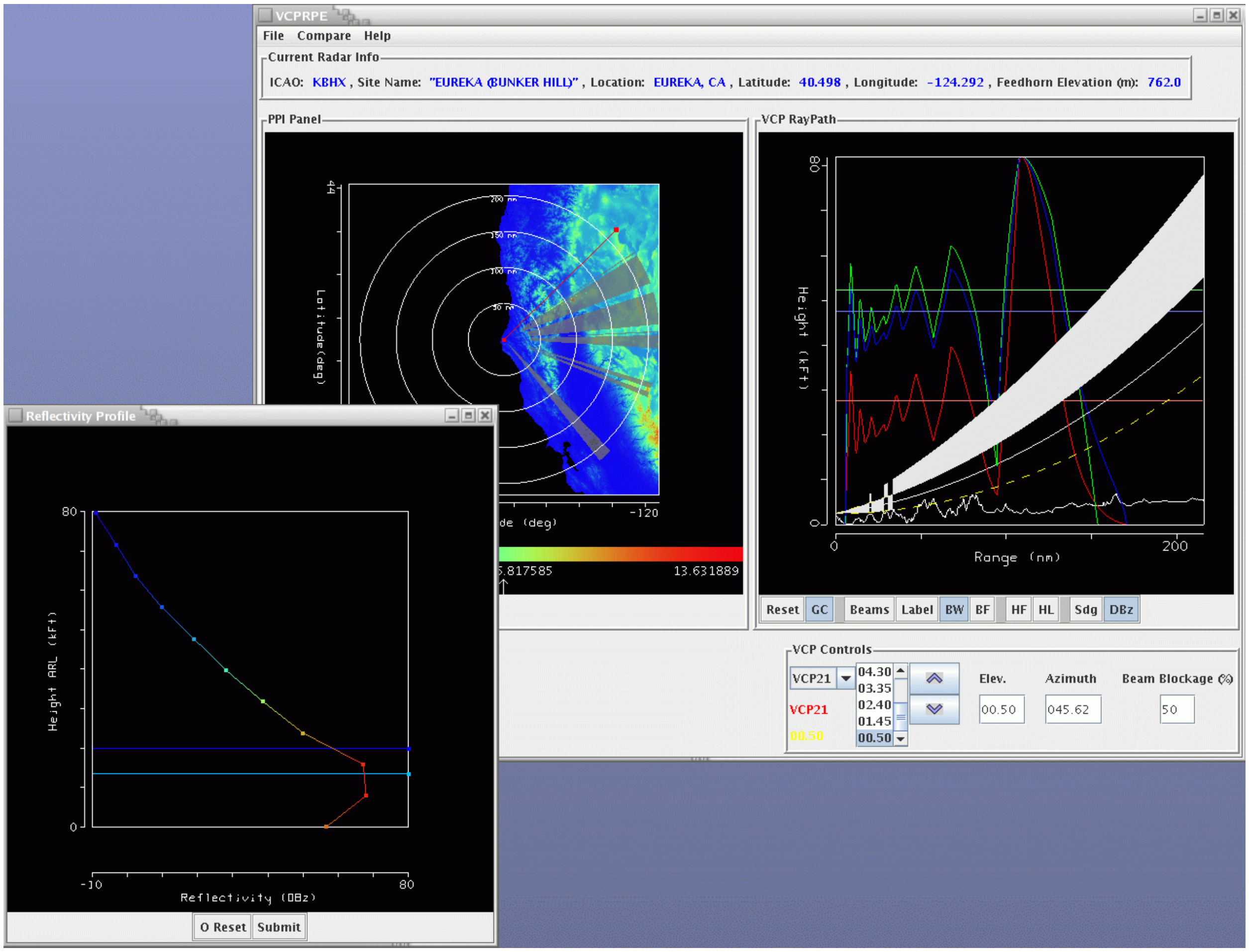
The Volume Coverage Pattern Explorer (VCPExplorer) was delivered to the National Weather Service (NWS) Warning Decision Training Branch (WDTB) in the Spring of 2004. Since then, the VCPExplorer has been used in the WDTB's Advanced Warning Operations Course (AWOC) in the fall of 2004 to qualitatively explore areas of potential radar error. Perhaps the greatest illustration the VCPExplorer impressed on the AWOC attendees was the fluctuation of radar-based algorithm output, such as the Probability of Hail (POH), due to 1) range from the radar and 2) choice of VCP.

WDTB has asked that the VCPExplorer be upgraded to illustrate radar precipitation estimation errors, as well as some refinement of the interface. These changes are currently being worked on. It is anticipated that the VCPExplorer will be used in the WDTB "Winter Weather" AWOC scheduled for December of 2006.

This project is ongoing.

Publications

Manross, K.L., J.G. LaDue, and G. Stumpf, 2005: The Volume Coverage Pattern Explorer: A new tool for visualizing radar beam paths. CD-ROM, *21st International Conf. on Information Processing Systems (IIPS)*, Amer. Meteor. Soc., San Diego, 5.5.



The VCPExplorer with Reflectivity Profile window. The VCPExplorer displays color-coded terrain and ground clutter (grey) in the "PPI Panel" (left Panel). Displayed in the "RHI Panel" (right) are the terrain (jagged white line), beam bottom (dashed yellow), Hybrid Scan (solid white), and algorithm output: POSH (green), SHI (red), and MEHS (blue). Algorithm output is based on the user selected Reflectivity Profile and the user selected VCP.

Investigation of the Use of Dual-Polarization Radar to Improve Quantitative Precipitation Estimation for Improving Flash Flood and Flood Detection, Warnings, and Forecasts – *Polarimetric Rainfall Estimation*

Ryzhkov (primary – CIMMS at NSSL)**, Schuur, Giangrande, Krause, Clabo**

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: CIMMS Task II – NSSL Project 5

Objectives

Improve upon radar-based rainfall estimation techniques.

Accomplishments

Analysis of newly acquired data, examination of outliers. During past year, we continued collecting data with the polarimetric prototype of the WSR-88D radar and validating the quality of rainfall products using micronet and mesonet rain gages. The primary focus was on the origin of outliers and their relation to the possible radar miscalibration and details of differential phase processing.

Climatological analysis of rain regimes based on disdrometer data. Over the past 7 years, 47,000 one-minute drop size distribution (DSD) measurements have been made by the National Severe Storms Laboratory 2D-video disdrometer. In a study of natural DSD variability, the large dataset was used to examine the relationship of the measured DSDs to season, a variety of storm and precipitation system types, continental and tropical precipitation, warm and cold season precipitation, surface temperature, and the height of the bright band. Among the most intriguing signatures seen in this study is the strong dependence of the observed DSDs on the freezing level height, providing evidence of the strong relationship between observed DSDs and environmental factors.

Dual-polarization radar/disdrometer/wind profiler comparisons. In the spring of 2005, in collaboration with the National Center for Atmospheric Research, a 2D-video disdrometer was placed at a location approximately 30 km south of the polarimetric KOUN WSR-88D radar. Combined with data collected with the KOUN radar, these disdrometer data are now being analyzed to investigate the ability of the retrieve drop size distribution parameters. Atmospheric wind profiler data are also being used in this study, the results of which are being reported in a series of papers being presented at the International Radar Conference in the Fall of 2005.

DSD retrieval. A new polarimetric algorithm for DSD retrieval has been developed to better understand the impact of DSD variability on the quality of rainfall estimation. The suggested procedure is similar to the NCAR method but is applicable for much larger variety of rain regimes.

Evaluation of rainfall products with OHD. Real-time and archived data from the polarimetric KOUN WSR-88D radar are being delivered to scientists at the National Weather Service/Office of Hydrology (OHD), where they are being evaluated for eventual use in operational hydrologic models. CIMMS scientists are actively collaborating with OHD in these analyses.

This project is ongoing.

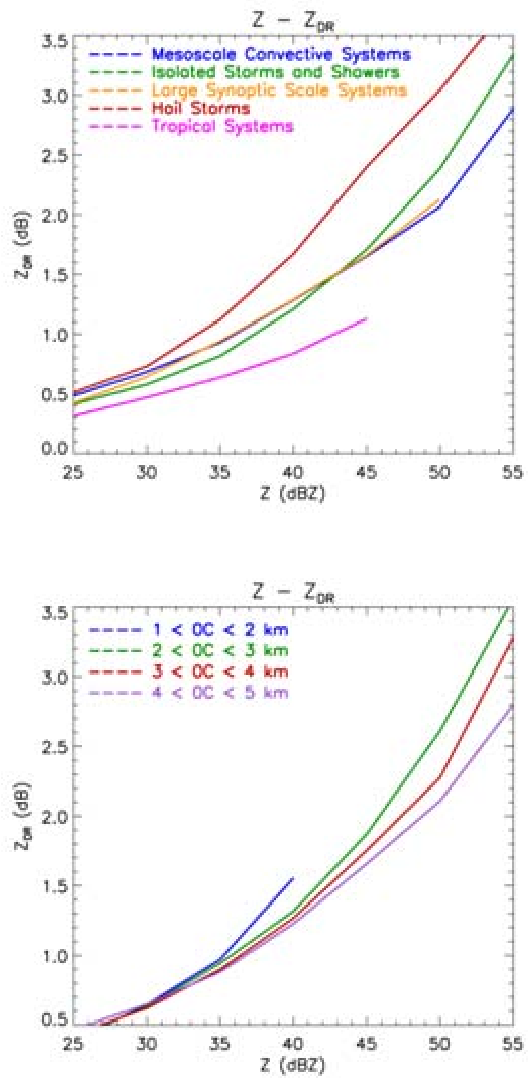
Publications

Ryzhkov, A.V., T. J. Schuur, D.W. Burgess, S. Giangrande, and D.S. Zrnic, 2005: The Joint Polarization Experiment: Polarimetric rainfall measurements and hydrometeor classification. *Bull. Amer. Meteor. Soc.*, **86**, 809-824.

Ryzhkov, A.V., S.E. Giangrande, and T.J. Schuur, 2005: Rainfall estimation with a polarimetric prototype of the WSR-88D radar. *J. Appl. Meteor.*, **44**, 502-515.

Ryzhkov, A.V., S.E. Giangrande, V. M. Melnikov, and T.J. Schuur, 2005: Calibration issues of dual-polarization radar measurements. *J. Atmos. Oceanic Technol.*, accepted.

Giangrande, S.E. and A.V. Ryzhkov, 2005: Calibration of dual-polarization radar in the presence of partial beam blockage. *J. Atmos. Oceanic Technol.*, accepted.



Plot of reflectivity vs. differential reflectivity by a) type of precipitation, and b) freezing level height. Differential reflectivity has been averaged over 5 dBZ reflectivity bins. In a), precipitation categories are Mesoscale Convective Systems (blue), Isolated Showers and Storms (green), Synoptic Systems (orange), Hail Storms (red), and Tropical Systems (purple). In b), categories are for freezing level heights of between 1 and 2 km (blue), 2 and 3 km (green), 3 and 4 km (red), and 4 and 5 km (purple).

Investigation of the Use of Dual-Polarization Radar to Improve Quantitative Precipitation Estimation for Improving Flash Flood and Flood Detection, Warnings, and Forecasts – ***Polarimetric Classification of Meteorological and Non-Meteorological Scatterers***

Schuur (primary – CIMMS at NSSL)**, Ryzhkov, P. Zhang, Heinselman, Giangrande, Bachmann**

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: CIMMS Task II – NSSL Project 5

Objectives

Utilize dual-polarization radar data to discriminate between meteorological and non-meteorological scatterers, as well as to classify hydrometeor types.

Accomplishments

Bright band detection. A polarimetric method for melting level detection has been developed and tested in real time using the data collected with the KOUN WSR-88D radar. The algorithm detects the top and bottom of the melting layer (ML). The top boundary of ML coincides with the freezing level, whereas the bottom of ML determines the onset of the bright band contamination of the radar rainfall estimates at longer distances from the radar. ML designations were validated using sounding data and the output of RUC model.

Hail size assessment. Data from the KOUN radar have been used to assess the ability of polarimetric radar to discriminate hail size. The study investigates the use of polarimetric variables (ZH, ZDR, rhohv, and KDP) for estimating hail size. A total of 106 hail reports from 17 hail-producing storms that occurred mostly during the spring of 2003 and 2004 were examined. The location of each hail report was matched to the closest polar coordinate and used to find associated polarimetric measures. Scatterplots of ZH, ZDR, rhohv, and KDP indicate that KDP and ZDR vs rhohv showed the best clustering of hail sizes less than and greater than 2.5 cm. However, discriminant analysis of the data reveals that the pairing of ZDR with rhohv distinguishes hail size best.

Insects/birds discrimination. Polarimetric properties of clear-echo radar returns associated with insects and birds have been examined using a large amount of the KOUN data. The magnitudes of differential reflectivity and differential phase, their azimuthal dependencies and diurnal cycles reveal substantial differences between polarimetric signatures of birds and insects. Spectral analysis of radar returns at orthogonal polarizations demonstrates that quite often birds and insects are mixed together. A successful separation of the contributions from insects and birds in the radar signal has been demonstrated using Doppler polarimetric processing technique.

Winter storms. Since the upgrade of the KOUN radar, polarimetric radar data have been collected in 15 winter weather events and several others where, though rain was observed at the surface, a low freezing level provided information on the transition from ice to water phase. Combined, these data provide statistical information that allows us to quantify the polarimetric characteristics of cold season precipitation in Oklahoma. Preliminary analyses of several events reveal the ability of the radar to discriminate between a variety of winter precipitation types, including freezing rain and regions of heavy wet snow.

This project is ongoing.

Publications

Zrnic, D.S. and A.V. Ryzhkov, 2004: Polarimetric properties of chaff. *J. Atmos. Oceanic Technol.*, **21**, 1017-1024.

Ryzhkov A.V., T.J. Schuur, D.W. Burgess, and D.S. Zrnic, 2005: Polarimetric tornado detection. *J. Appl. Meteor.*, **44**, 557- 570.

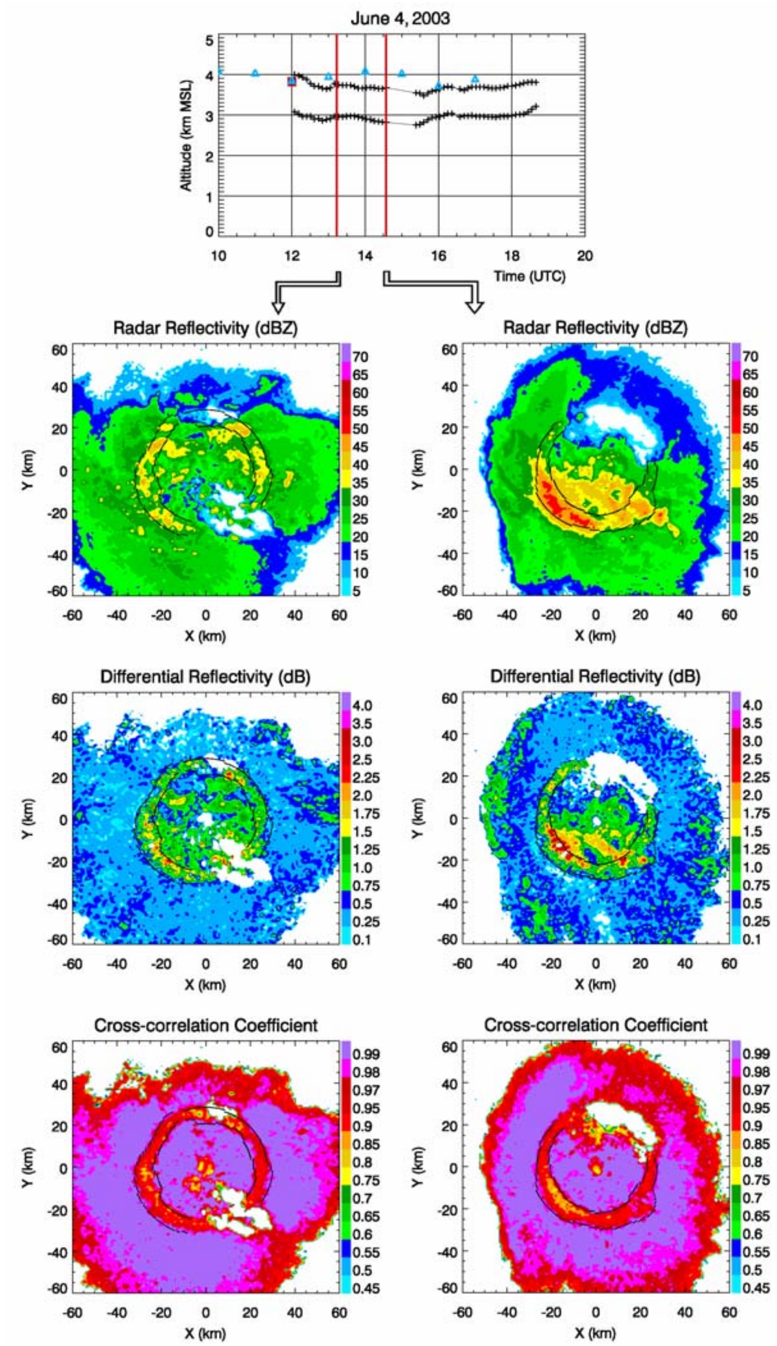
Zrnic, D.S., V.M. Melnikov, and A.V. Ryzhkov, 2005: Correlation coefficients between horizontally and vertically polarized returns from ground clutter. *J. Atmos. Oceanic Technol.*, accepted.

Heinselman, P.L., and A.V. Ryzhkov, 2005: Validation of polarimetric hail detection. *Wea. Forecasting*, submitted.

Schuur, T.J., A.V. Ryzhkov, D.W. Burgess, and D.S. Zrnic, 2004: Polarimetric radar observations of tornadic debris signatures. CD-ROM, *22nd Conf. on Severe Local Storms*, Hyannis, MA, Amer. Meteor. Soc., 8B.3.

Heinselman, P.L. and A.V. Ryzhkov, 2004: Hail detection during the Joint Polarization Experiment. CD-ROM, *11th Conf. on Aviation, Range, and Aerospace Meteorology*, Hyannis, MA. Amer. Meteor. Soc., J1.3.

Zhang, P., A.V. Ryzhkov, and D.S. Zrnic, 2004: Detection of birds and insects using polarimetric observations. CD-ROM, *11th Conf. on Aviation, Range, and Aerospace Meteorology*, Hyannis, MA, Amer. Meteor. Soc.
Brandes, E.A., and A.V. Ryzhkov, 2004: Hail detection with polarimetric radar. CD-ROM, *11th Conf. on Aviation, Range, and Aerospace Meteorology*, Hyannis, MA, Amer. Meteor. Soc., P5.10.
Giangrande, S.E., and A.V. Ryzhkov, 2004: Polarimetric method for bright band detection. CD-ROM, *11th Conf. on Aviation, Range, and Aerospace Meteorology*, Hyannis, MA, Amer. Meteor. Soc., P5.8.



Top panel depicts mean melting layer top and bottom detections as a function of time for a 4 June 2003 squall line event. Triangles on the plot indicate RUC model analysis output freezing level heights for the KOUN location. The red square indicates the local NWS OUN sounding freezing level height. Bottom panel depicts select KOUN PPI images (times denoted with red lines on the top panel) with overlaid volume scan melting layer detections.

Investigation of the Use of Dual-Polarization Radar to Improve Quantitative Precipitation Estimation for Improving Flash Flood and Flood Detection, Warnings, and Forecasts – *Radar Polarimetry at Shorter Wavelengths*

Ryzhkov (primary – CIMMS at NSSL)**, Zrnic, Krause**

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: CIMMS Task II – NSSL Project 5

Objectives
Evaluate prospects of polarimetry utilization for shorter wavelength weather radars; evaluate polarimetric capabilities of the C-band DRS radars and modify existing S-band polarimetric algorithms for the use at C-band.

Accomplishments
Radar polarimetry at S-band has matured to a point that the U.S. National Weather Service plans to retrofit the WSR-88D network with components for polarimetric measurements. There is a growing interest in utilizing polarimetry at C- (5 cm) and X- (3 cm) wavebands to satisfy the needs of national weather services outside U.S. and to complement existing WSR-88D radars with X-band polarimetric "gap fillers" in the regions of poor coverage.

In the past year, we performed extensive theoretical simulations of polarimetric radar variables at C- and X-bands using scattering computations and large archive of disdrometer data collected in central Oklahoma. In addition, the quality of the data collected by the DRS C-band polarimetric data has been evaluated and recommendations on the use of polarimetric algorithms for rainfall estimation and radar echo classification at C-band have been formulated.

This project is ongoing.

Investigation of the Use of Dual-Polarization Radar to Improve Quantitative Precipitation Estimation for Improving Flash Flood and Flood Detection, Warnings, and Forecasts – *Dual-Polarization Algorithm Development and Testing*

Krause (CIMMS at NSSL)

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: CIMMS Task II – NSSL Project 5

Objectives
Demonstrate real-time feasibility of dual polarimetric algorithms; demonstrate improved quantitative precipitation estimates; demonstrate improved hydro classification of radar echoes; support scientific Investigation of dual polarimetric data.

Accomplishments
The tasks accomplished during the period fall into 3 categories: ORPGD creation and testing, dual polarimetric algorithm development, and miscellaneous. The ORPGD was created in the period, tested, and then modified again to handle a new format. The dual polarimetric algorithms from the current prototype were moved into the ORPG's data and algorithmic framework and modified to run as processes within the ORPG. This new ORPG was renamed ORPGD, "D" for dual polarimetric as it runs the both the legacy algorithms and the dual polarimetric specific algorithms from the KOUN data stream.

Dual polarimetric algorithm development for the period included creating the melting layer detection algorithm and then applying this algorithm to the hydro-classification scheme and the QPE algorithms. The QPE algorithm was modified to recalculate KDP in order to improve rainfall estimates. Addition features were added to the prototype to allow for live calibration, output of polarimetric data for Kessler Farm, and a number of other miscellaneous tools in support of the dual polarimetric effort.

Interactions with the Office of Hydrology regarding the independent validation and verification of the QPE estimates are ongoing. Multiple data sets were rerun for their assessments, technical problems discussed and solved, and meetings attended in support of this important project. Support was also provided to WRDD in the delivery of preliminary information about all polarimetric algorithms for the ROC.

The WDT MOU, for which I was the primary contact, was delivered on 10/6/2004 and version 2 was delivered on 2/17/2005. The MOU was also supported by phone and a few site visits.

This project is ongoing.

Investigation of the Use of Dual-Polarization Radar to Improve Quantitative Precipitation Estimation for Improving Flash Flood and Flood Detection, Warnings, and Forecasts – *Polarimetric Signal Processing*

Melnikov (primary – CIMMS at NSSL)**, Carter, Ryzhkov, Zrnic, Ivic**

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: CIMMS Task II – NSSL Project 5

Objectives

Develop methods for differential reflectivity and differential phase calibrations on the WSR-88D. Explore new possibilities for specific differential phase measurements; devise methods for eliminating noise impact on polarimetric variables.

Accomplishments

Methods for calibrating differential reflectivity and differential phase on WSR-88D were developed and tested. Methods are based on test signal and solar flux measurements and processing of the differential phases of signals scattered by the ground. Accuracies of methods are 0.1 dB for differential reflectivity and 2 degrees for the differential phase. Automatic dual-pol calibration is being developed on WSR-88D KOUN. A new procedure for processing differential phase has been developed and tested to improve the quality of polarimetric rainfall estimates. The procedure mitigates effects of inadequate radial resolution and non-uniform radar beam filling.

Methods to eliminate noise impact on differential reflectivity and the correlation coefficient were devised. The methods allow measurements of dual-pol variables at low signals (weak clouds and precipitation, distant storms). The attached figure contains two radar fields of the vertical cross section of the correlation coefficients obtained with the conventional and proposed algorithms. The echo is from a low reflectivity cloud. One can see that the values of the conventional coefficients (left figure) are far from unity which is because of weak signals. The values in the right figure are close to unity which is expected for clouds. The proposed method should be used in the recognition of scatterers.

This project is ongoing.

Publications

Zrnic, D.S., V.M. Melnikov, and A.V. Ryzhkov, 2004: Use of backscatter differential phase in weather surveillance radars. CD-ROM, *IEEE International Geosciences and Remote Sensing Symp.*, Anchorage, Al, paper C9.1.

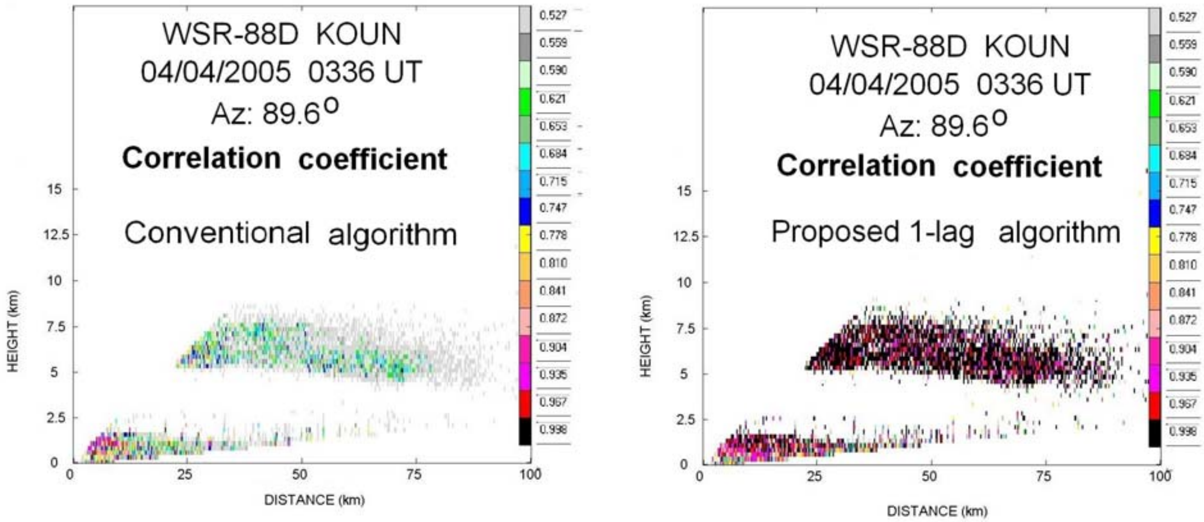
Fang, M.**,** R. J. Doviak and V. Melnikov, 2004: Spectrum width measured by WSR-88D: Error sources and statistics of various weather phenomena. *J. Atmos. Oceanic Technol.*, **21**, 888-904.

Melnikov, V.M., and D. S. Zrnic, 2004: Estimates of large spectrum width from autocovariances. J. *Atmos. Ocean Technol.*, **21**, 969-974.

Zrnic, D.S., V.M. Melnikov, and J.K. Carter, 2005: Calibrating differential reflectivity on the WSR-88D. NOAA/NSSL Report. 33 pp.

Zrnic, D.S., V.M. Melnikov, and A.V. Ryzhkov, 2005: Correlation coefficients between horizontally and vertically polarized returns from ground clutter. *J. Atmos. Oceanic Technol.*, accepted.

Zrnic, D.S., A. Zahrai, S. Torres, I. Ivic, C. Curtis, and V. Melnikov, 2005: Development of advanced techniques using the NOAA's WSR-88D research radar. CD-ROM, *21st International Conf. on IIPS*, San Diego, CA, paper 5.9.



Vertical cross-sections of the correlation coefficients obtained with the conventional (left) and proposed (right) algorithms.

Investigation of Advancements in Radar Technology toward the Improvement of Hazardous Weather Detection and Warnings – *Mitigation of Range and Velocity Ambiguities*

Torres (primary – CIMMS at NSSL), **Sachidananda**

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: CIMMS Task II – NSSL Project 7

Objectives

Resolve WSR-88D range and Doppler velocity ambiguities to the levels required for the efficient observation of severe weather, culminating in significantly improved WSR-88D data quality when implemented on the Open Radar Data Acquisition (ORDA) sub-system. The increased data quality will result in an improved ability for the WSR-88D to detect severe weather, flash floods, winter storms, and provide aviation forecasts.

Accomplishments

In the WSR-88D, the range and Doppler velocity ambiguity problems are coupled such that trying to alleviate one of them worsens the other. Special techniques are necessary to resolve both ambiguities to the levels required for the efficient observation of severe weather. Over the last decade, two techniques have emerged as viable candidates to address the mitigation of range and velocity ambiguities in the WSR-88D thus reducing the amount of purple haze obscuration currently encountered during the observation of severe phenomena. These are: systematic phase coding and staggered pulse repetition time (PRT). The two techniques are complementary since they offer advantages at specific elevation angles; hence, they can be simultaneously incorporated into the same volume coverage pattern (VCP).

In conjunction with the National Center for Atmospheric Research, we have recently recommended and transferred to the Radar Operations Center of the National Weather Service an algorithm for the initial deployment of range and velocity ambiguity mitigation techniques on the RDA subsystem. The algorithm, referred to as SZ-2, is based on systematic phase coding that uses the SZ(8/64) code and will replace the Doppler half of split cuts at the lowest elevation angles of the antenna beam.

Research continued for both SZ phase coding and the staggered PRT technique. Both algorithms were refined to meet WSR-88D operational requirements and tested on data collected with the KOUN radar. In addition, a novel staggered PRT spectral processing technique was developed. This, in conjunction with the ground clutter filter for staggered pulses developed in previous years, makes the staggered PRT technique a viable candidate to replace the legacy Batch mode at intermediate elevation angles.

This project is ongoing.

Publications

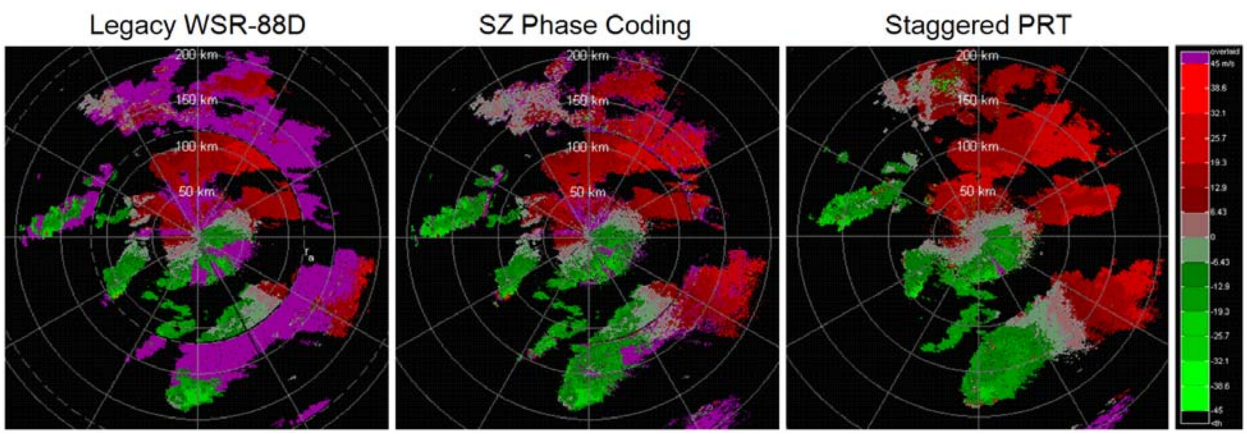
Torres, S., 2005: Range and velocity ambiguity mitigation on the WSR-88D: Performance of the SZ-2 phase coding algorithm. CD-ROM, *21st International Conf. on Interactive Information and Processing Systems (IIPS) for Meteorology, Oceanography, and Hydrology*, San Diego, CA, Amer. Meteor. Soc., paper 19.2.

Ellis, S. M., M. Dixon, G. Meymaris, S. Torres, and J. Hubbert, 2005: Radar range and velocity ambiguity mitigation: Censoring methods for the SZ-1 and SZ-2 phase coding algorithms. CD-ROM, *21st International Conf. on Interactive Information and Processing Systems (IIPS) for Meteorology, Oceanography, and Hydrology*, San Diego, CA, Amer. Meteor. Soc., paper 19.3.

Zrnic, D., A. Zahrai, S. Torres, C. Curtis, and I. Ivic, 2005: Development of advanced techniques using the NOAA's WSR-88D research radar. CD-ROM, *21st International Conf. on Interactive Information and Processing Systems (IIPS) for Meteorology, Oceanography, and Hydrology*, San Diego, CA, Amer. Meteor. Soc., paper 5.9.

Torres, S., and D. Zrnic, 2004: Range and velocity ambiguity mitigation techniques for the WSR-88D weather radar. CD-ROM, *International Geoscience and Remote Sensing Symp. 2004*, Anchorage, AK, Inst. of Electrical and Electronics Engineers, 1727-1729.

Torres, S. M., Y. Dubel, and D. S. Zrnic, 2004: Design, implementation, and demonstration of a staggered PRT algorithm for the WSR-88D. *J. Atmos. Oceanic Technol.*, **21**, 1389-1399.



Doppler velocity PPI displays of severe storms in central Oklahoma obtained using the legacy WSR-88D (left panel), SZ phase coding (central panel), and staggered PRT (right panel) algorithms. Purple color denotes an unrecoverable Doppler velocity due to overlaid echoes. Both SZ phase coding and staggered PRT techniques remove significant amounts of purple haze resulting in displays with larger areas of recovered Doppler velocities.

Investigation of Advancements in Radar Technology toward the Improvement of Hazardous Weather Detection and Warnings – *Improvement of Spectral Moment and Polarimetric Variable Estimates using Decorrelating Transformations on Oversampled Range Data*

Torres (primary – CIMMS at NSSL), **Curtis**, **Ivic**

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: CIMMS Task II – NSSL Project 7

Objectives

Exploit range oversampling followed by a decorrelation transformation for faster data temporal acquisition and denser spatial sampling as needed to satisfy some of the evolutionary requirements for the WSR-88D.

Accomplishments
Range oversampling followed by a decorrelation transformation is a novel method for increasing the number of independent samples from which to estimate the Doppler spectrum, its moments, as well as several polarimetric variables on pulsed weather radars. Since errors of estimates increase with increased antenna rotation speed, the decreased errors associated with decorrelation permit the antenna to rotate faster while maintaining the current errors of estimates. It follows that storms can be surveyed much faster than is possible with current processing methods. Alternatively, for a given volume scanning time, errors of estimates can be greatly reduced. These are important considerations in WSR-88D operations. This technique can be advantageously exploited in a combination of faster data temporal acquisition and denser spatial sampling as needed to satisfy some of the evolutionary requirements for the WSR-88D.

During the past year research focused on practical issues involving the implementation of oversampling and “whitening” techniques within the WSR-88D operational environment.

A general implementation framework for oversampling and “whitening” techniques was developed. This realization is computationally efficient and capable of accommodating any of the processing techniques under consideration. Adaptive schemes were investigated in which optimum pseudowhitening transformations are chosen according to the meteorological phenomena being observed by the radar.

Range oversampling techniques were tested on real dual-polarization data collected with the KOUN radar. The recently upgraded digital receiver allows collection of time series data at sampling rates higher than the legacy sampling rate. Results on real data were used to confirm theoretical and simulation findings. Compared to standard processing of signals using a matched filter, it was verified that a reduction in variance by a factor equivalent to the oversampling factor is achieved.

With practical implementation issues in mind, an alternative realization of the decorrelation concept using finite-impulse-response (FIR) filters was investigated. Because hardware implementation of pseudowhitening transformations is only possible through custom hardware designs, the approach to range decorrelation using an FIR (Finite Impulse Response) filter may be more attractive since it lends itself to an efficient hardware implementation (many digital receivers feature built-in user-configurable FIR filters.) This scheme was successfully tested offline on simulated and real data.

Preliminary results on real data have demonstrated that techniques employing range oversampling are feasible candidates to maintain data quality without sacrificing acquisition time in future enhancements of the national network of weather surveillance radars.

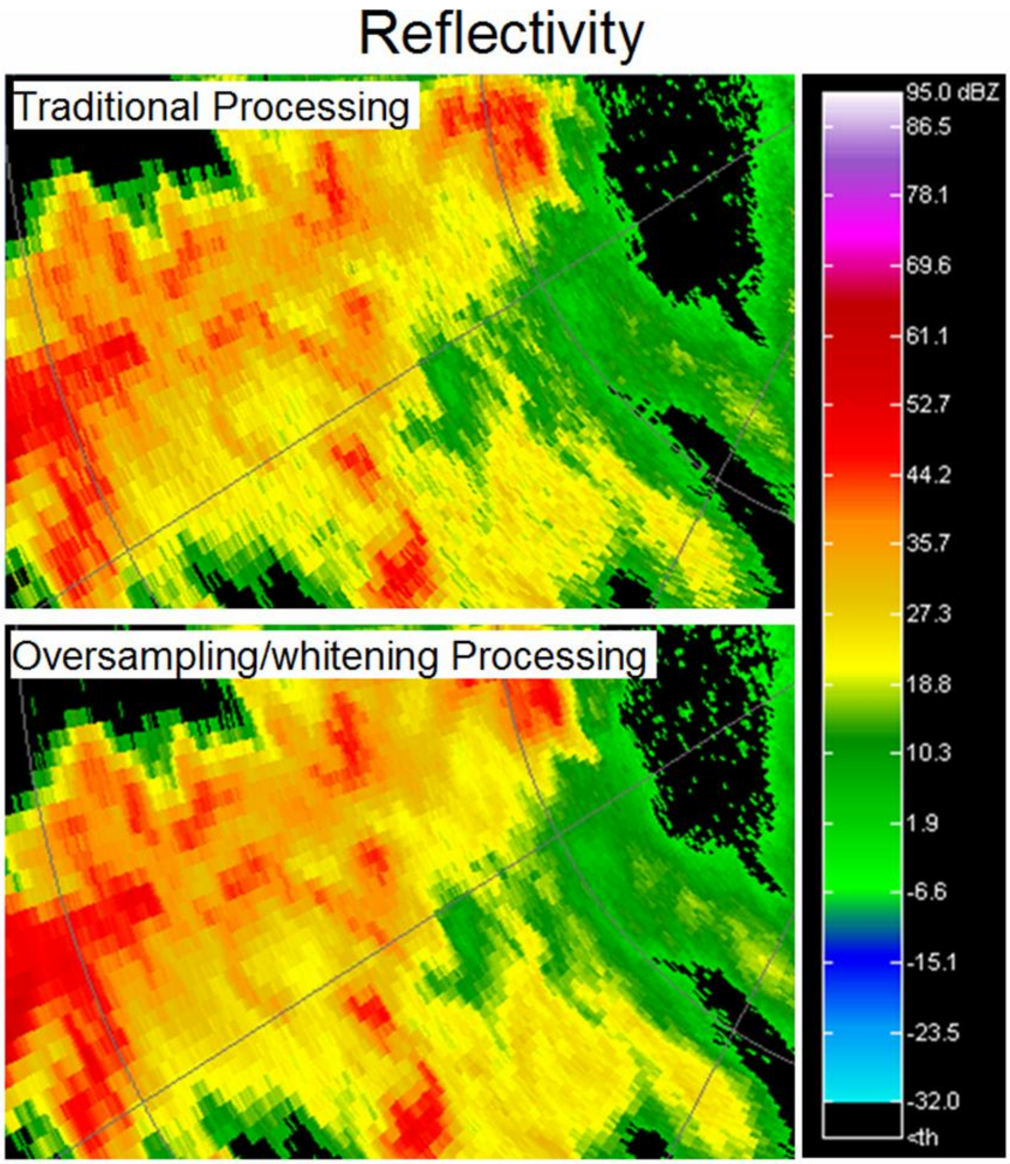
This project is ongoing.

Publications

Torres, S. and I. Ivic, 2005: Demonstration of range oversampling techniques on the WSR-88D. CD-ROM, *32nd International Conf. on Radar Meteorology*, Albuquerque, NM, Amer. Meteor. Soc.

Ivic, I., A. Zahrai, and S. Torres, 2005: Decorrelation in range of oversampled weather radar signals using FIR filter. CD-ROM, *32nd International Conf. on Radar Meteorology*, Albuquerque, NM, Amer. Meteor. Soc.

Torres, S. M., C. D. Curtis, and J. R. Cruz, 2004: Pseudowhitening of weather radar signals to improve spectral moment and polarimetric variable estimates at low signal-to-noise ratios. *IEEE Trans. Geosci. Remote Sensing*, **42**, 941-949.



Reflectivity field of storms in central Oklahoma processed using traditional sampling (top) and oversampling and whitening (bottom). As expected, "smoother" fields obtained with oversampling and whitening are an indication of reflectivity estimates with lower statistical errors than those obtained with legacy processing.

Investigation of Advancements in Radar Technology toward the Improvement of Hazardous Weather Detection and Warnings – *Super Resolution Radar Data*

Curtis (primary – CIMMS at NSSL)**, Forren, Torres**

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: CIMMS Task II – NSSL Project 7

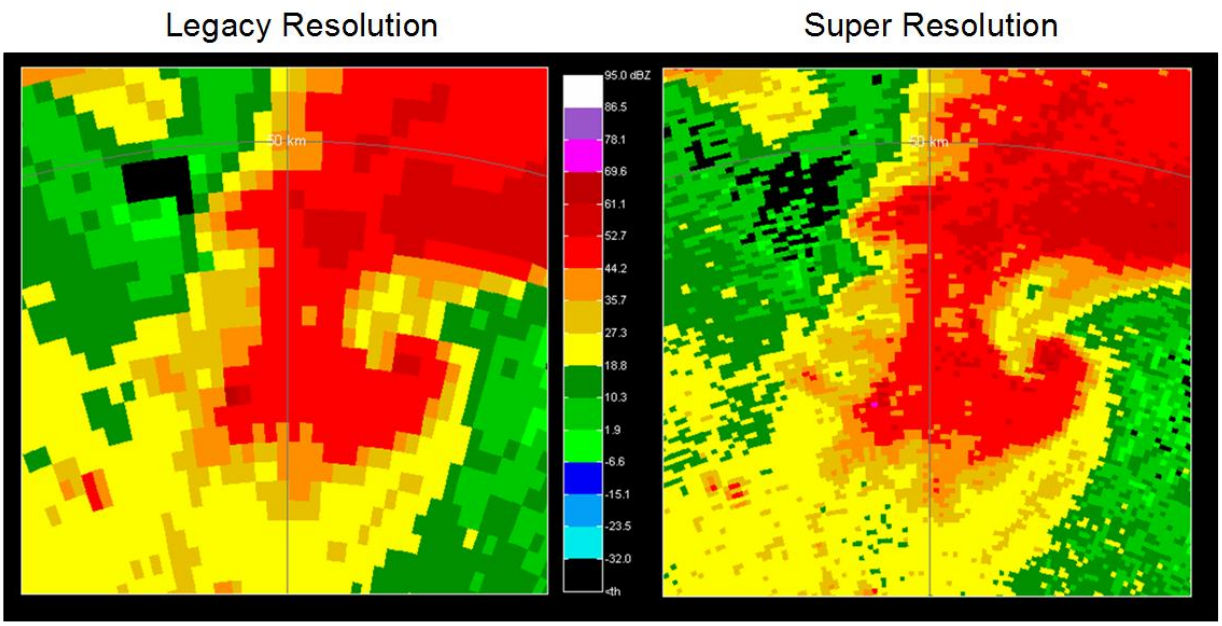
Objectives

Increase the detection range of mesocyclone and tornado vortex signatures; increase the visibility of the reflectivity signatures with super-resolution data; increase warning times for severe thunderstorms and tornadoes; and improve radar detection of severe weather, flash floods, and winter storms.

Accomplishments
We investigated the use of windows with overlapping radials. This included simulations to study the results of windows on the effective beam width and on the errors of estimates. Time series data were processed offline using Matlab® to compare the performance for different windows and processing schemes. C-language offline processing was updated to allow processing with windows.

We continued support for processing and manipulating time series and base data for meteorological and engineering evaluation purposes.

This project is ongoing.



May 10, 2003 03:42 UTC, F3 tornado - Edmond, OK Tornado signature between -30 and 30 deg Data collected with KOUN at 0.5 deg elevation Data processed using legacy resolution for reflectivity (1km, 1 deg) and using super-resolution (250m, 0.5 deg) using overlapping 1 deg radials and a Blackman window.

Investigation of Advancements in Radar Technology toward the Improvement of Hazardous Weather Detection and Warnings – *Radar Data Quality for the Korean Meteorological Administration (KMA)*

Burcham (primary – CIMMS at NSSL), Jain, **J. Zhang,** You (KMA)

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: CIMMS Task II – NSSL Project 7

Objectives
Evaluate radar data quality issues of Korean Meteorological Administration (KMA) radars and identify solutions to improve their radar data quality.

Accomplishments
In collaboration with KMA scientists, NSSL and CIMMS scientists have evaluated KMA datasets for data quality issues. Primary issues are centered on residual ground clutter, anomalous propagation, sea clutter, sun strobes, point targets, and velocity dealiasing.

Progress has been made in the analysis of Korean radar data and the performance of existing data quality algorithms. Adjustments in the algorithms have been made to increase performance and reliability. Progress has also been made toward a prototype system to satisfy Korea's radar data quality requirements. This includes making the data quality system functional under KMA's specified operating system (SuSE Linux), and adding the capability to process datastreams from two radars simultaneously. Tests and evaluations of the program are proceeding.

This project is ongoing.

Investigation into the use of Phased Array Radar Technology for Improving Hazardous Weather Detection and Warnings – *National Weather Radar Testbed*

Adams, Benner, Burcham, Curtis, Forsyth (co-primary – NSSL)**, Heinselman,** Hondl, Jain, **Priegnitz, Staples, Suppes, J. Thompson,** Zahrai, **Zrnic** (co-primary – NSSL)

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: CIMMS Task II – NSSL Project 8

Objectives

Analyze and modify the National Weather Radar Testbed (NWRT) Phased Array Radar (PAR) for scientific and engineering evaluation; perform engineering analyses of PAR data to identify and assess data quality issues associated with the system; use these analyses to prioritize and resolve identified issues; provide meteorological analyses of PAR data to evaluate the utility of using the PAR technology for meteorological purposes.

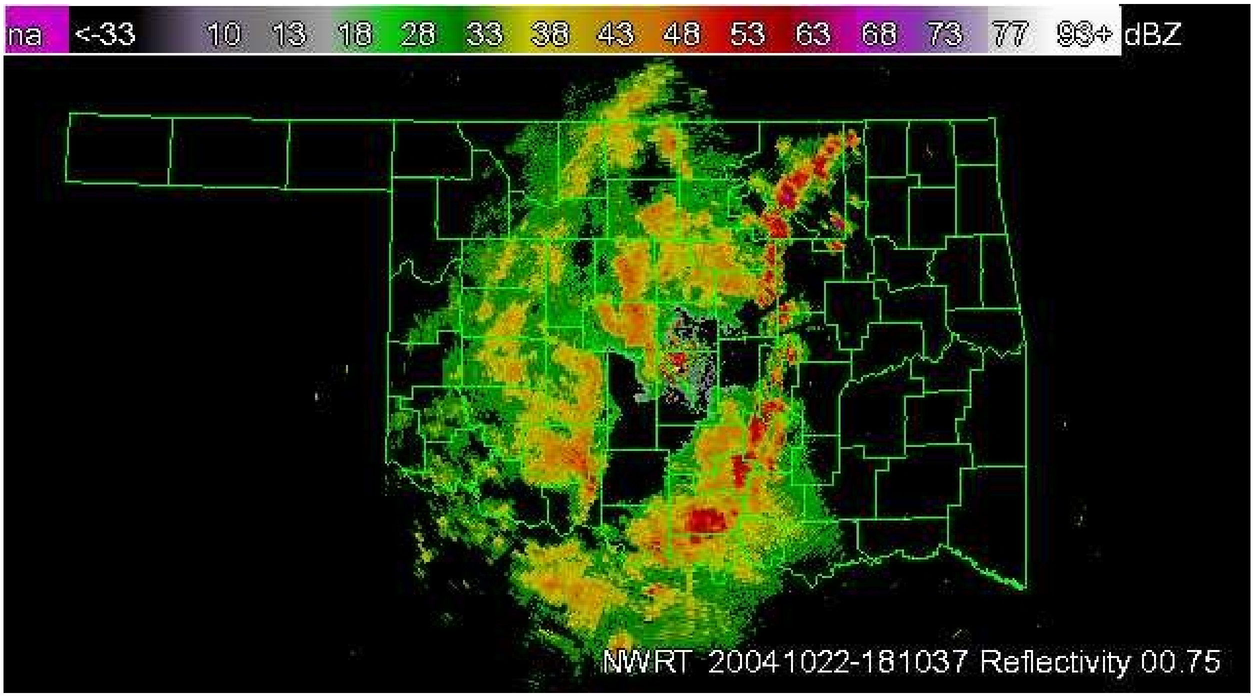
Accomplishments

Efforts continue to make the system ready to evaluate its potential as an eventual replacement for the WSR-88D. Work has included designing new scan and data collection strategies, performing engineering analysis of the data, conducting configuration control of the software and hardware, identifying and repairing software defects, general testing, and improving the functionality of the system. Collaborative work between NSSL, CIMMS/OU, Lockheed-Martin, the FAA, and Basic Commerce and Industries (BCI) staff have led to the resolution of data quality and operational issues identified in the new system. Work continues to improve the data quality and usability of the NWRT so that it can become a one-of-a-kind research tool. Data also are collected as interesting meteorological events arise (see figure below).

This project is ongoing.

Publications

Forsyth, D. E., J. F. Kimpel, D. S. Zrnic, R. Ferek, J. F. Heimmer, T. McNellis, J. E. Crain, A. M. Shapiro, R. J. Vogt, and W. Benner, 2005: Progress report on the National Weather Radar Testbed (Phased-Array). CD-ROM, *21st International Conf. on Interactive Information Processing Systems for Meteor., Oceanography, and Hydrology*, San Diego, CA, Amer. Meteor. Soc., 19.5.



One of several data sets collected for analysis by the NWRT this year, from 22 October 2004.

Investigation into the use of Phased Array Radar Technology for Improving Hazardous Weather Detection and Warnings – *Phased Array Radar Beam Multiplexing*

Adams (primary – CIMMS at NSSL)**, Curtis, Orescanin**

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: CIMMS Task II – NSSL Project 8

Objectives

Increase the speed of volumetric scans and provide for adaptive scan capability.

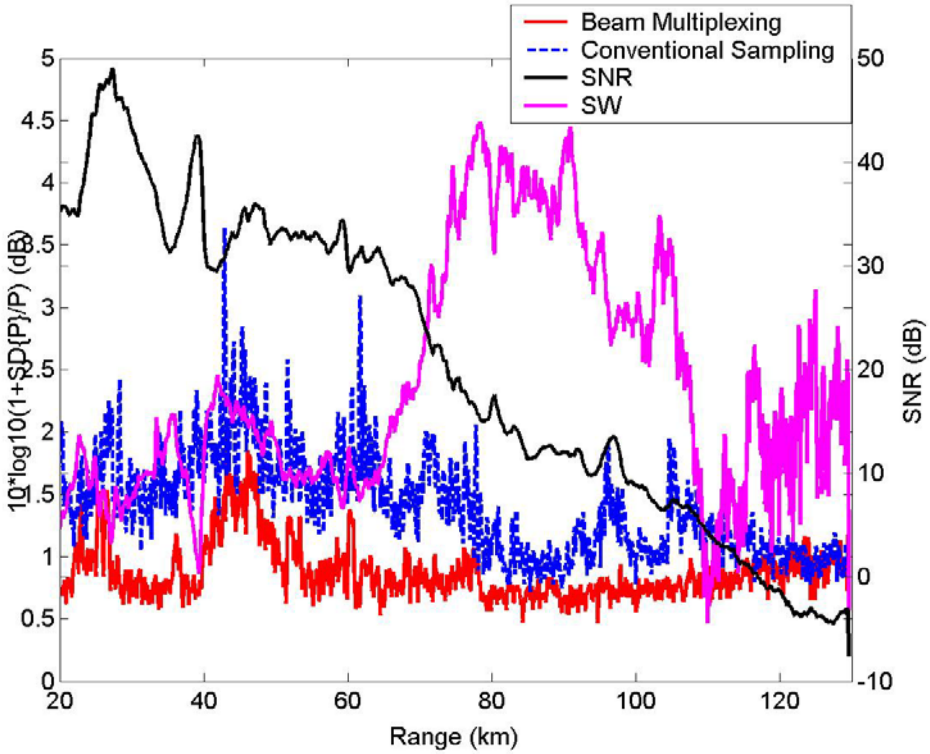
Accomplishments

Investigation and analysis of beam multiplexing strategies were conducted. An experiment was conducted on May 2nd, 2005 starting at 15:07:5 UTC. The PAR operates at a frequency of 3.2 GHz. PRT and pulse width are 1 ms and 1.57 ìs, respectively. The sampling frequency was 2.5 MHz which resulted in range oversampling by a factor of 4. This provides the possibility of further improvement of the performance with the whitening technique. Several beam multiplexing stems have been created.

This project is ongoing.

Publications

Forsyth, D. E., J. F. Kimpel, D. S. Zrnic, R. Ferek, J. F. Heimmer, T. McNellis, J. E. Crain, A. M. Shapiro, R. J. Vogt, and W. Benner, 2005; Progress Report on the National Weather Radar Testbed (Phased-Array). CD-ROM, *21st International Conf. on Interactive Information Processing Systems for Meteor., Oceanography, and Hydrology*, San Diego, CA. Amer. Meteor. Soc., 19.5.



Standard deviation of reflectivity.

Investigation into the use of Phased Array Radar Technology for Improving Hazardous Weather Detection and Warnings – ***Phased Array Radar Scheduler***
Priegnitz (CIMMS at NSSL)

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

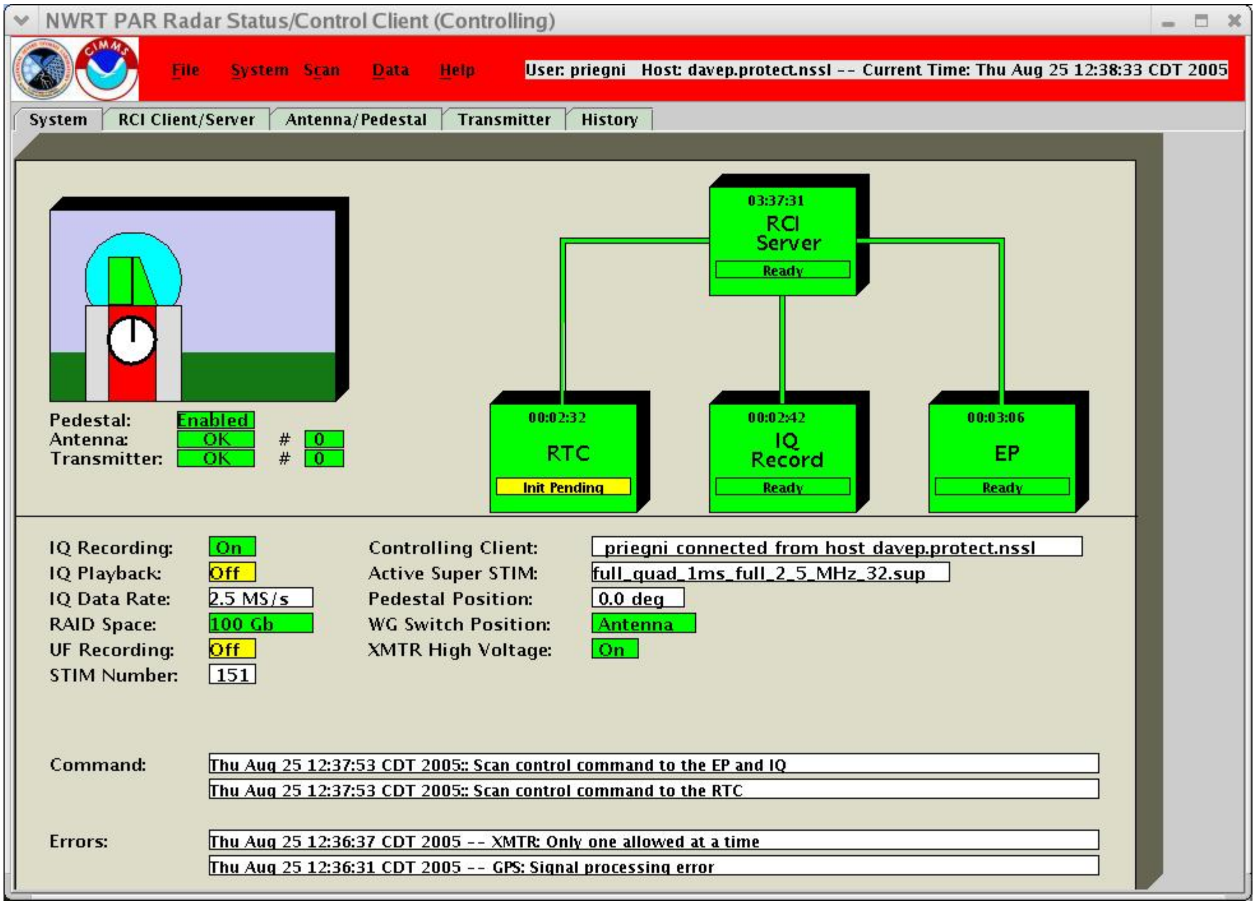
Funding Agency: CIMMS Task II – NSSL Project 8

Objectives
Design a new Radar Scheduler that can be run remotely and by multiple users.

Accomplishments
A major goal of the National Weather Radar Testbed is to provide access to researchers both inside and outside the Norman community. The Radar Scheduler that was delivered with the system lacks the flexibility to be run remotely and by more than one user at a time.

A new Radar Scheduler, named the Radar Control Interface (RCI) has been developed to overcome the limitations of its predecessor. It is based on a client-server model which allows many clients to be run concurrently. At a given moment, only one client can control radar system resources. However, all clients can monitor system status and perform non-control functions (i.e., browse logs, schedule resources) regardless of which client is in control. A sample RCI Client display is shown in the figure below.

This project is ongoing.



Sample Radar Control Interface (RCI) display for a controlling client.

Investigation into the use of Phased Array Radar Technology for Improving Hazardous Weather Detection and Warnings – ***Phased Array Radar IQ Data Browser***

Priegnitz (CIMMS at NSSL)

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: CIMMS Task II – NSSL Project 8

Objectives

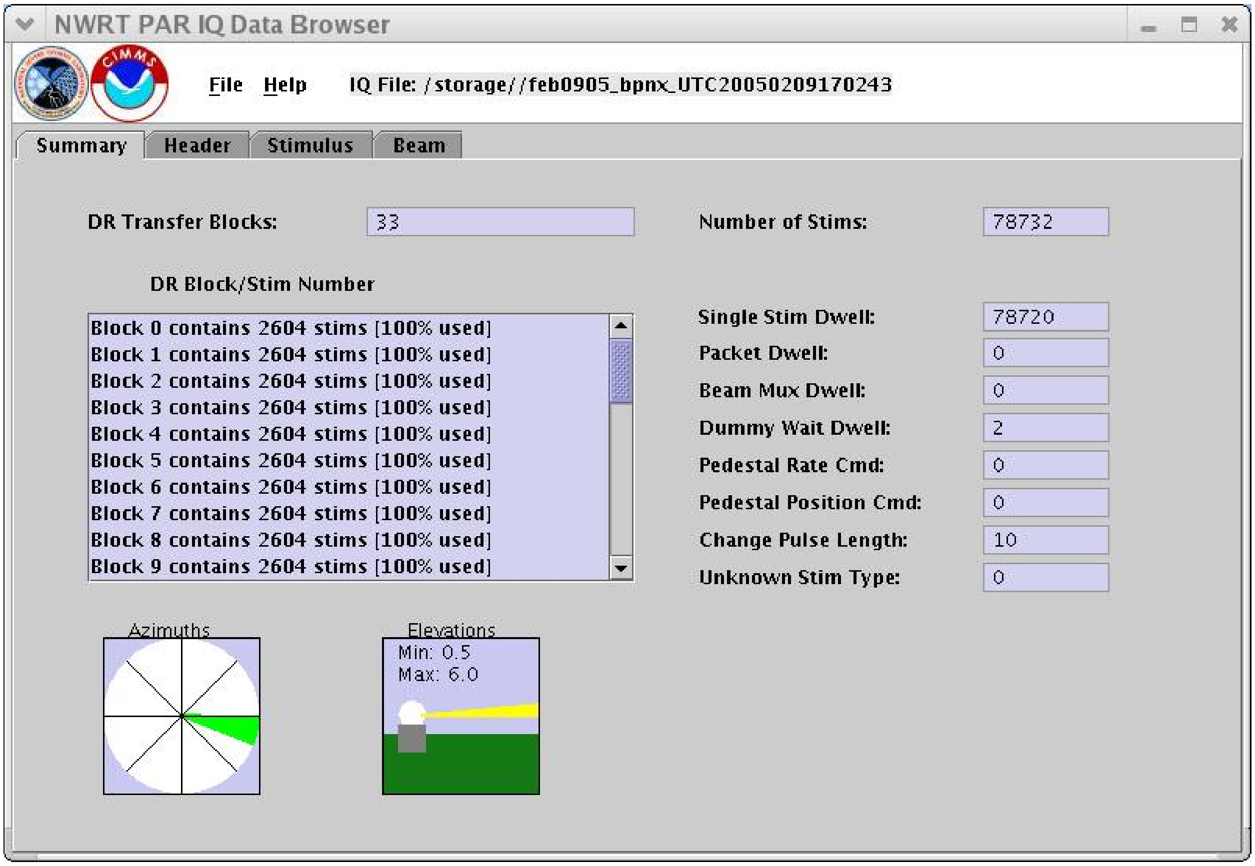
Develop a software tool to analyze time series data from the phased array radar for quality control.

Accomplishments

While operating the phased array radar it became apparent that new software tools needed to be developed to analyze various output data sets. Several software tools were already available to look at moment output (i.e., WDSS-II and IRAS). However, problems in the generation and display of moment data indicated that software was needed to analyze the time series (IQ) data as well. Time series data files themselves are on the order of 100 times larger than their corresponding moment files. How to display the data is not straight forward since time series data contain two components (an I and a Q value) for each pulse.

A simple Java-based tool, called IQBrowse, has been developed to display various properties of an NWRT time series data file. All header fields are displayed along with summaries of each stimulus (pulse) and beam. The figure below shows an example of one component of an IQBrowse display.

This project is ongoing.



Sample IQBrowse Summary display for an NWRT time series data file.

Investigation into the Use of Phased Array Radar Technology for Improving Hazardous Weather Detection and Warnings – *Phased Array Radar Scalable Signal Processing*

Adams, Benner, J. Thompson (primary – CIMMS at NSSL)

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: CIMMS Task II – NSSL Project 8

Objectives
Provide scalable signal processing capacity to meet current and future signal processing requirements; Handling more complex and extensive signal processing algorithms and greater data rates will surpass the capability of the current system.

Accomplishments
A scalable signal processing concept was investigated. Both a commercially available "open systems" components and high speed crossbar switching were identified to provide scalability for increasing DSP loads. Assembly of a working prototype was initiated and ingest of PAR IQ data has been successfully demonstrated and the results validated.

This project is ongoing.

Investigation into the Use of Phased Array Radar Technology for Improving Hazardous Weather Detection and Warnings – *Phased Array Radar Simultaneous Archiving of IQ and Moments Data*

Adams, Benner, Priegnitz, Suppes, J. Thompson (primary – CIMMS at NSSL)

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: CIMMS Task II – NSSL Project 8

Objectives
Provide new capability to simultaneously archive IQ and moment data for the Phased Array Radar system.

Accomplishments
A concept was developed making use of currently available hardware resources from spares. Environmental Processor software running on two separate SKY platforms was modified to simultaneously accept IQ data. Working cooperatively with a modified scheduler, both IQ archiving and moment archiving are now possible.

This project has been completed.

Analysis of Weather Radar Observations of Severe Convection to Understand Severe Storm Processes and Improve Warning Decision Support – *WSR-88D Algorithm Evaluation and Improvement, and Data Quality*

Patchin, Garfield, Wiegman, Setzer, Schoor, Garwood, Seelen, Jones, McCarroll, Murnan, Vogt (primary – ROC), George, Fresch

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: CIMMS Task II - ROC

Objectives
Perform data quality assessments for ORDA; verify the validity of new radar blockage maps; update handbook documentation; design and fabricate prototypes of new trigger amplifier and modulator assemblies for the WSR-88D transmitter; develop and test new radio frequency generator components; develop procedures for deploying wireless LAN equipment; assist with testing a new radar data display capability; perform outreach activities and provide public affairs support.

Accomplishments
Below is a summary of the activities of CIMMS students at the Radar Operations Center:

Patchin's major project has been assisting the Open System Radar Data Acquisition (ORDA) data quality working group. She created numerous spreadsheets comparing different aspects of radar data from ORDA to the legacy system. She created, reviewed, and updated presentations made for the committee's weekly meetings. She contributed to all reports written by her mentor, Robert Lee, about ORDA data quality. She also has helped from time to time with the radar blockage studies by capturing terrain and blockage images and archiving them by radar location.

Garfield contributed to a project intended to verify the validity of new radar blockage maps. In order to accomplish this, blockage that occurred during stratiform precipitation events was compared with the new blockage maps created from high-resolution terrain data to assess the accuracy of the new maps. Stratiform precipitation events were chosen because the areal coverage of such events aid in the identification of blockage. In addition to this, the new blockage maps were compared with the older blockage maps and terrain data to identify any discrepancies in the new maps. This was done for the 0.5 degree tilt and the next highest tilt. Additionally, he has been supporting scientists comparing the output of the NEXRAD Snow Accumulation Algorithm (SAA) with and without a preprocessing algorithm (the Enhanced Preprocessing (EPRE) algorithm) which attempts to filter out data blocked by terrain or contaminated by ground clutter due to anomalous propagation. The original SAA was developed without the EPRE, but due to the addition of alternate scanning strategies SAA was implemented with the EPRE.

Wiegman was involved in data quality analysis of the ORDA. He played back data sets from both the ORDA and legacy processors, capturing data for statistical analysis in spreadsheets, thus aiding senior scientists develop a quantitative tool for meaningful comparisons between the ORDA and legacy radar products. Additionally, Tim assisted the Site Specific Scanning Strategy (S4) working group by creating a software program that can help analyze volume coverage patterns and algorithms used in the NEXRAD system.

Setzer has proven to be a valuable asset to the ROC in systems management. He is both knowledgeable and dedicated and is able to quickly diagnose problems on a wide variety of systems – normally with no direct assistance from the senior technicians. He works well with the users, maintaining his composure even in adverse situations.

Schoor worked on updating the Federal Meteorological Handbook, Number 11, Doppler Radar Meteorological Observations (FMH-11), using his superb computer skills to update radar imagery, graphics, and figure captions into the manuscript. Additionally, Greg worked with the ROC database staff documenting database structure in support of a system migration from MS Access to SQL software. Finally, Greg worked closely with a senior meteorologist in the ROC Applications Branch to analyze proposed changes to the Radar Echo Classifier algorithm.

Garwood provided invaluable support to the ROC Engineering Branch by assisting (and sometimes taking the lead) in designing and fabricating prototypes of new trigger amplifier and modulator assemblies for the WSR-88D transmitter. He researched various technical sources to identify suitable components for the application, and used commercial engineering software to perform the printed circuit board component layout. He developed test procedures to verify proper operation, designing and building special test fixtures specifically for the task, then assisted in identifying multiple vendors for the critical components. Garwood traveled to the National Reconditioning Center in Kansas City to consult with the engineers and technicians who will perform the modification for the network of WSR-88D radar systems, and generated the modification procedures for performing the work. He redlined our engineering drawings for configuration control, and updated our maintenance manuals for the technicians in the field. His efforts have saved the ROC many thousands of the dollars that would otherwise have been spent on outside engineering services. The system modifications promise to save the government over $12,000 per month in repair costs throughout the network.

Seelen helped ROC engineers develop and test new radio frequency (RF) generator components for the WSR-88D Doppler weather radar system. The RF generator is critical to the proper operation of the radar system. The development effort was undertaken to ensure units would be available should the legacy generator become unsupportable. He also developed a cooling modification for an equipment rack in the engineering lab. This equipment rack houses high performance equipment which is under evaluation for insertion into the WSR-88D network for radar product generation. The cooling mod permits the ROC to safely test six different computer systems simultaneously, greatly improving our efficiency. He played a key role in the redesign of the pedestal simulator, and performed extensive troubleshooting of the embedded microprocessor controller. The simulator is used in the development and troubleshooting of major modifications to the antenna control functions of the radar system, and will be instrumental to the efficient development of the upcoming dual polarization mod. Use of the simulator relieves contention for scarce test bed resources. Seelen also built 38 complex electrical cables to be used in the Open RDA modification. He used available materials on hand, plus approximately $100 worth of purchased parts, to fabricate what otherwise would have cost the government over $15,000 to procure.

Jones developed procedures for deploying the wireless LAN equipment. The system in question is used to restore radar communications on an emergency basis and was used to restore communications to the San Diego radar after wildfires destroyed local communication lines. His work resulted in a concise set of procedures by which ROC engineers or technicians can easily deploy the equipment on an emergency basis without outside assistance. He has performed outstanding work on pedestal simulators. These devices were developed by the University of Oklahoma to simulate a radar pedestal, allowing the ROC to perform parallel activities on the test bed with only a single antenna. He discovered the chip in the simulators is obsolete and he found a suitable replacement. At the same time, he discovered bugs in the original firmware programming and corrected those errors.   Finally, he is now redesigning the system so a future chip replacement will be possible without extensive rework. In addition he currently is helping define more detailed requirements for an update of this simulator. Jones is assisting with the development of a light emitting diode (LED) aircraft warning light modification for radars near flight operations. This project will replace conventional lighting systems that require bulb replacement every year with a system having a ten year life.

McCarroll assisted with testing a new radar data display capability. His testing covered both the exiting Sun hardware based radar display and a proof of concept, web based system. His findings were turned over to developers to improve the end products. He also helped develop and checkout a web-based general display system for weather data. This involved writing scripts to call up existing weather web pages for a public display system.

Murnan has been an essential outreach specialist in the ROC. He has worked extensively with the Director's office and the Public Affairs office on a variety of projects the past year. One of his key projects has been to create new digital photography images and organize existing photos for updating the hallway displays in the ROC North building for the purpose of using as a reference while giving tours. He has worked with all the Norman NOAA agencies to update file photography and video imagery for NEXRAD, the Phased Array Radar test bed, Norman Weather Forecast Office, National Severe Storms Lab, and the Storm Prediction Center. An expert in setting up audio/visual equipment, Murnan has been instrumental in installing new cameras, microphones, monitors, and cabling for both live viewing and recording of ROC software training classes in Norman and Oklahoma City.

Many of these projects are ongoing.

Analysis of Weather Radar Observations of Severe Convective Storms to Understand Severe Storm Processes and Improve Warning Decision Support – *NEXRAD Technology Transfer*

Burgess (primary – CIMMS at NSSL)**, Scharfenberg, Smith, Manross, Farmer**

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: CIMMS Task II – ROC

Objectives

Develop, mature, and transition technology, including meteorological algorithms, into the WSR-88 baseline; improve WSR-88D data quality and usefulness.

Accomplishments

During the report period, progress was made on several tasks. The first was meteorological support to transfer dual-polarization (DP) technology to the NEXRAD program. Because a 3-db sensitivity loss accompanies current plans for DP implementation on WSR-88D radars (result of receiver beam splitting into horizontal and vertical channels), a field test was conducted with the Norman NWS Office to measure any loss of capability associated with the 3-db loss. Based on data collected during spring 2005 (April-

June), the only noted losses were slightly less "clear-air" return and a slight loss in vertical wind profile capability (Fig. 1). Detection of clear-air boundaries and all precipitation mode information (data display, severe storm algorithms, and precipitation estimation algorithms) was not negatively affected. In addition, two new DP algorithms (precipitation estimation and particle type estimation) were examined and tested. New, updated algorithm documentation was delivered to the Radar Operation Center (ROC) for first NEXRAD implementation.

A new algorithm developed at NSSL, Vorticity Tracks, was documented for the ROC, its output was tested against the baseline NEXRAD Mesocyclone Detection Algorithm (MDA), and its experimental use at NWS Forecast Offices was summarized. The new algorithm makes use of linear least-squares derivatives in an innovative way to estimate vorticity. Tracks are achieved by accumulating output for a series of volume scans, much like is done with precipitation accumulation. Initial testing and experimental use suggests that the new algorithm is superior to MDA in several ways: 1) more continuity in output because there is no reliance on the Storm Tracking Algorithm (which can occasionally fail), 2) less susceptibility to errors in the input velocity data, and 3) provides gradient information instead of just single point output. NWS Offices found the end-of-storm vorticity tracks very useful for later storm damage surveys because of the accuracy and completeness of the summary information.

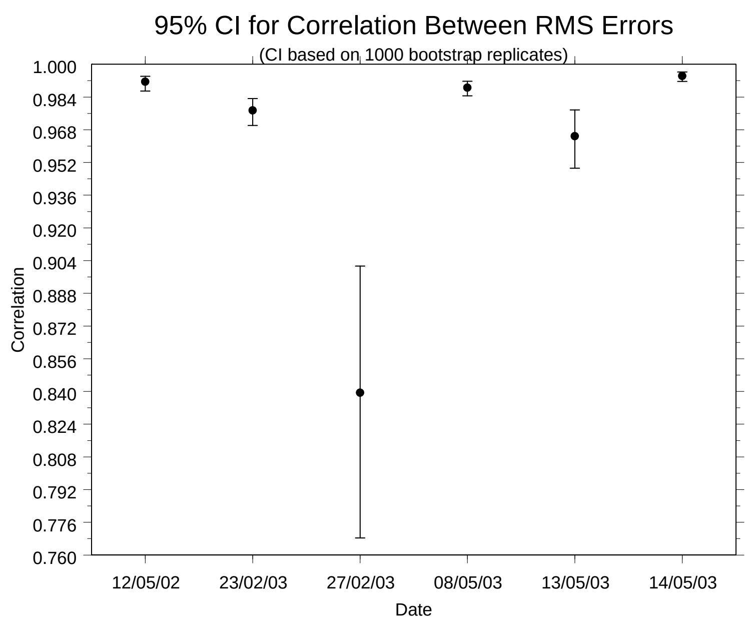
The existing NSSL Radar Level II Database was maintained and enhanced. Selected WSR-88D and TDWR cases were archived and other important auxiliary data collected. Auxiliary data included satellite data, numerical model data, lightning data, and text data (including surface METAR and mesonet data, sounding data, NWS watches/warnings, and Storm Data). In addition, NEXRAD prototype dual-polarization data from KOUN were archived and auxiliary data were collected for selected winter storm, convective storm, and heavy precipitation cases. These data are used by a host of NSSL scientists in the development of new WSR-88D applications.

This project is ongoing.

Publications

Burgess, D.W., and M.A. Fresch, 2006: The ROC/NSSL Technology Transfer MOU: A success storm in radar applications technology transfer. Preprints, *22nd IIPS Conf.*, AMS Annual Meeting, Atlanta, GA.

Scharfenberg, K. A., K. L. Elmore, E. Forren, V. Melnikov, and D. S. Zrnic, 2005: Estimating the impact of a 3-dB sensitivity loss on WSR-88D data. CD-ROM, *32nd Conf. on Radar Meteorology*, Albuquerque, NM, Amer. Meteor. Soc., P12R.9.



Correlation of VWP Wind Profiles for full data and data with 3-dB sensitivity loss.

Emergency Mobile Radar

Biggerstaff (primary – OU School of Meteorology)**,** Hondl, **Crum**, **Carrie**

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: CIMMS Task II - ROC

Objectives

Install the Weather Decision Support System Integrated Information (WDSS-II) in a Shared Mobile Atmospheric Research and Teaching (SMART) radar to serve as an emergency backup for the WSR-88D network during land-falling hurricanes.

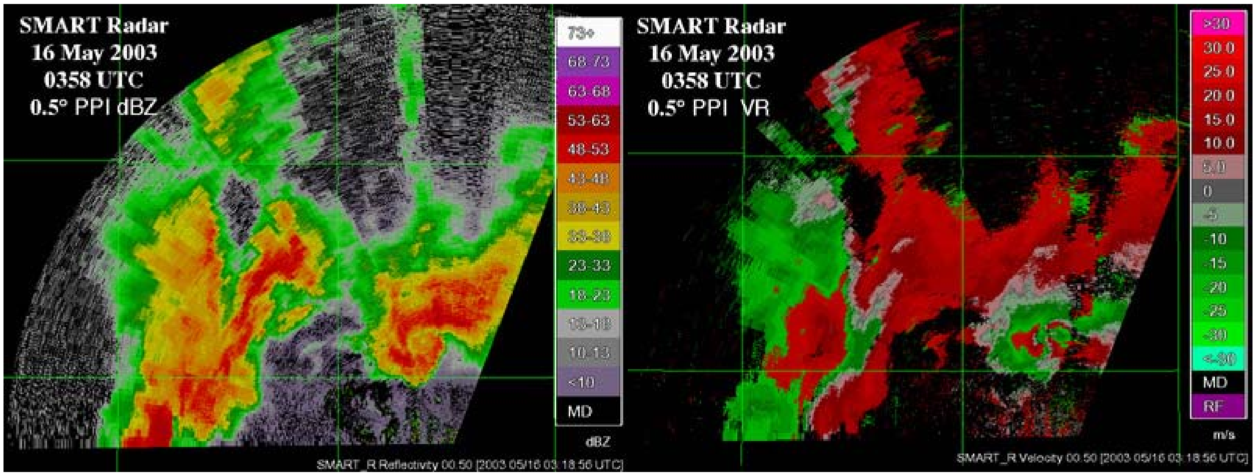
Accomplishments

This project intends to prepare SMART radars for emergency use by the National Weather Service as backups to the WSR-88D system during landfalling hurricanes. We have tested ingest of SMART radar data into WDSS-II and have modified software to improve performance. Hardware required for project was purchased and CIMMS personnel received training on WDSS-II software. ROC engineering received CISCO training on wireless LAN radio communications as well, in support of this effort. WDSS-II was then integrated into the cab of one of the SMART radars and its real-time ingest and display of SMART radar data were demonstrated.

This project is ongoing.

Publications

Biggerstaff, M. I., L. J. Wicker, J. Guynes, C. Ziegler, J. M. Straka, E.N. Rasmussen, A. Dogget IV, L. D. Carey, J. L. Schroeder, and C. Weiss, 2005: The Shared Mobile Atmospheric Research and Teaching (SMART) Radar: A collaboration to enhance research and teaching. *Bull. Amer. Meteor. Soc.*, **86**, 1263-1274.



Display of SMART radar data in WDSS-II for raw files collected during a tornadic supercell observed on 16 May 2003 in the Texas panhandle.

Improving Tornado Detection with WSR-88D Data using Spectral Analysis

T-Y Yu (primary – OU School of Electrical and Computer Engineering), **Shapiro**, **Yeary**

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency – CIMMS Task III – CSTAR

Objectives

Develop an advanced algorithm to improve tornado detection based on both Level I and Level II data.

Accomplishments

A novel tornado detection algorithm has been developed based on a combined system of fuzzy-logic and neural networks and is termed neuro-fuzzy TDA (NFTDA). This hybrid system can automatically examine all the relevant information to make an objective decision for tornado detection. The performance of the algorithm is optimized through automated training based on a neural network approach. Currently, the input of NFTDA includes the following information: spectral signature, azimuthal shear, reflectivity, and the signal-to-noise ratio. The algorithm is designed to be flexible enough so that additional information can be easily incorporated into an operational system. The NFTDA has been implemented and tested using the NSSL research WSR-88D (KOUN) Level I time series data. The preliminary results show a promising extension of tornado detection in range compared to the NSSL TDA.

The NFTDA is demonstrated here using the KOUN data collected from a tornado outbreak in a region north of Oklahoma City on May 9, 2003. The NFTDA results are denoted by red circles in the figure. The NSSL TDA was applied to the KOUN Level II data and the results (termed TDA-KOUN) are shown in blue downward triangles. The universal time (UT) of detection for TDA-KOUN is the same as the one for the NFTDA and is denoted by red color. Moreover, the tornado damage path and the TDA results from the Oklahoma City WSR-88D (KTLX), provided by the NWS Weather Forecast Office (WFO) in Norman, are also included in the figure for comparisons. The results of operational TDA with the KTLX data (termed TDA-KTLX) are denoted by black upward triangles. Note that the tornado was closer to the KTLX than the KOUN during the entire period. The range between the tornado and KLTX is approximately 25 to 30 km, while the range between KOUN and the tornado varies from 35 to 55 km. It is evident that all the three results agree reasonably well with the damage path from 3:29 to 3:55 UT, except the TDA-KTLX identifies two extra locations at 3:49 and 3:54 UT. After 3:55 UT two false locations were detected by TDA-KOUN at 4:01 UT and no tornado was detected from that time to the end of the tornado, while the NFTDA can still provide reliable detection that is consistent with the damage path. For this case, the maximum range for reliable TDA-KOUN detection (3:55 UT) is approximately 43 km. On the other hand, the NFTDA can detect the tornado at least at the range of 55 km at 4:19 UT. Moreover, the NFTDA can provide robust detection without any false detection in this case.

This project is ongoing.

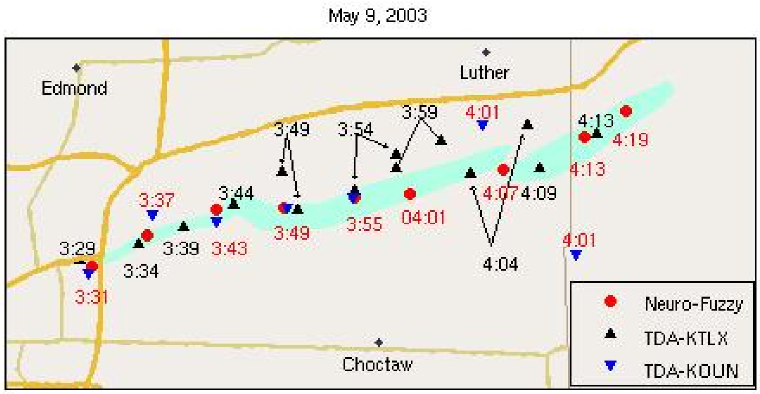
Publications

T.-Y. Yu, A. Shapiro, D. Zrnic, M. Foster, D. Andra, R. Doviak, and M. Yeary, 2004: Tornado spectral signature observed by WSR-88D. CD-ROM, *22nd Conf. on Severe Local Storms*, Hyannis, MA, Amer. Meteor. Soc.

M. Yeary, Y. Zhai, T.-Y. Yu, S. Nematifar, and A. Shapiro, 2005: Spectral signature calculations and target tracking for remote sensing. Preprints, *IEEE Transactions on Instrumentation and Measurement.*

Y. Wang, T.-Y. Yu, M. Yeary, A. Shapiro, D. Zrnic, M. Foster, and D. Andra, 2005: Tornado detection using a neuro-fuzzy method. CD-ROM, 32nd Conf. on Radar Meteorology, Albuquerque, NM, Amer. Meteor. Soc.

Zhang, G., T.-Y. Yu, and R. J. Doviak, 2005: Angular and range interferometry to refine weather radar resolution. *Radio Sci.*, **39**, RS3013, doi:10.1029/2004RS003125.



Results of the newly developed neuro-fuzzy tornado detection algorithm.

The Enhancement of Radar Retrievals by the Use of Higher Moments of Drop Spectrum

Y. Kogan (primary – CIMMS at OU)**, Z. Kogan, Mechem**

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: U.S. DOE

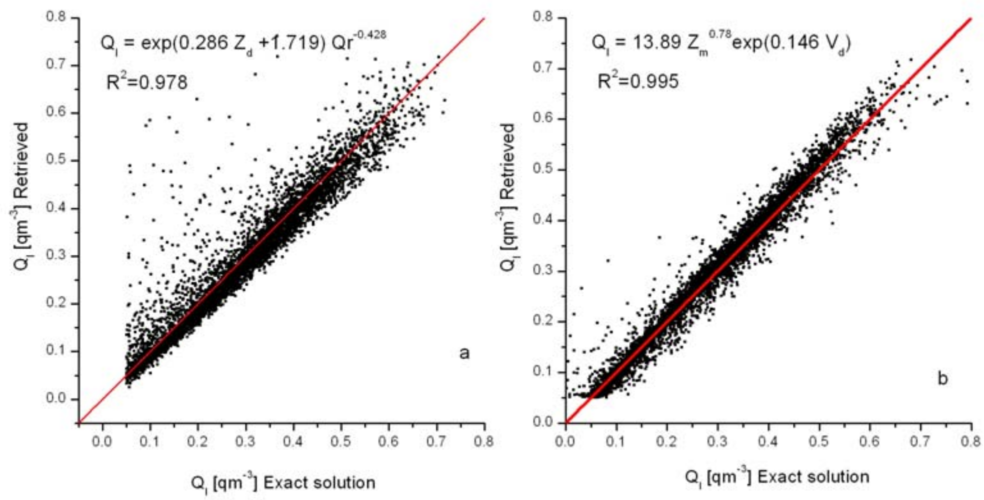
Objectives

Improve retrievals of cloud and drizzle parameters based on Doppler radar.

Accomplishments

We evaluate the relationship between radar reflectivity and cloud parameters using data from a large-eddy simulation model with size-resolving microphysics. Based on simulations of a marine stratocumulus cloud observed during the Atlantic Stratocumulus Transition Experiment we show that both cloud liquid water and precipitation flux are very sensitive to the drizzle mixing ratio and/or Doppler velocity parameter. For all drizzle conditions cloud liquid water retrievals can be substantially improved when information on the drizzle mixing ratio or Doppler velocity is included in retrieval algorithm. The use of the Doppler velocity leads to the most accurate retrievals. In clouds with substantial amounts of drizzle (R> 2mm/day) Z-R relationships can also be improved with information on drizzle mixing ratio or Doppler velocity. The inclusion of the latter produces the most accurate retrievals. Our study strongly suggests that the velocity parameters collected by Doppler cloud radars should be incorporated in future retrievals of liquid water content and precipitation flux.

This project is ongoing.



The comparison of cloud liquid water retrievals based on: (a) reflectivity and drizzle water (Qr), and (b) reflectivity and Doppler velocity, (Vd). Units: Ql and Qr in g/g, Zd in dBZ, Zm in mm6/m3.

Continued Support for the Internet-Based Delivery of WSR-88D Level II Data in Near Real Time (IRaDS)

Droegemeier, Martin (primary – CAPS), Sinclair

NOAA Strategic Goal 3 *(Serve Society's Need for Weather and Water Information)*

Funding Agency: CIMMS Task III – ROC and OU Vice President for Research

Objectives

Provide radar data transmission to the government and private sector.

Accomplishments

IRaDS is a program of the University of Oklahoma developed to provide radar data transmission, at cost. The IRaDS program transitions award-winning Collaborative Radar Acquisition Field Test (CRAFT) research results to a full-time operational service for the public. IRaDS was established as a top-tier source to provision data to the government and private sector. The IRaDS program began April 2004. A NOAA MOA established OU as a top-tier node for Level-II radar on 5 April 2004. To date, staff has established about 90 percent of the desired operational infrastructure. Products have been defined, including bulk weather data and a value-added re-seller approach. A weather technology vendor database has been established containing over 300 prospects. Problems with the reliability of NOAA/NWS data availability from the regional centers to the top-tier providers threatened program viability and greatly slowed market growth. However, with aggressive leadership to solve the issues, all eight of OU's original client contracts were renewed for the coming year. More than 20 additional prospects have shown levels of interest.

This project is ongoing.

Publications

Martin, J. D., and K. K. Droegemeier, 2005: An Internet-based top-tier service for streaming Level II data: CRAFT becomes an operational system. CD-ROM, *21st International Conf. on Interactive Information Processing Systems (IIPS) for Meteorology, Oceanography, and Hydrology*, San Diego, CA, Amer. Meteor. Soc.

Climate Change Monitoring and Detection

Detection and Attribution of Climate Change Using Climate Indices for the United States

Karoly (primary – OU School of Meteorology), **Ruppert**, Easterling, Lawrimore

NOAA Strategic Goal 2 *(Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond)*

Funding Agency: CIMMS Task III – NOAA OGP

Objectives

Evaluate US climate extremes indices from observational data and climate model simulations, document the observed changes in climate extremes in the US over the 20th century, and attribute the observed changes to specific climate forcings, where possible.

Accomplishments

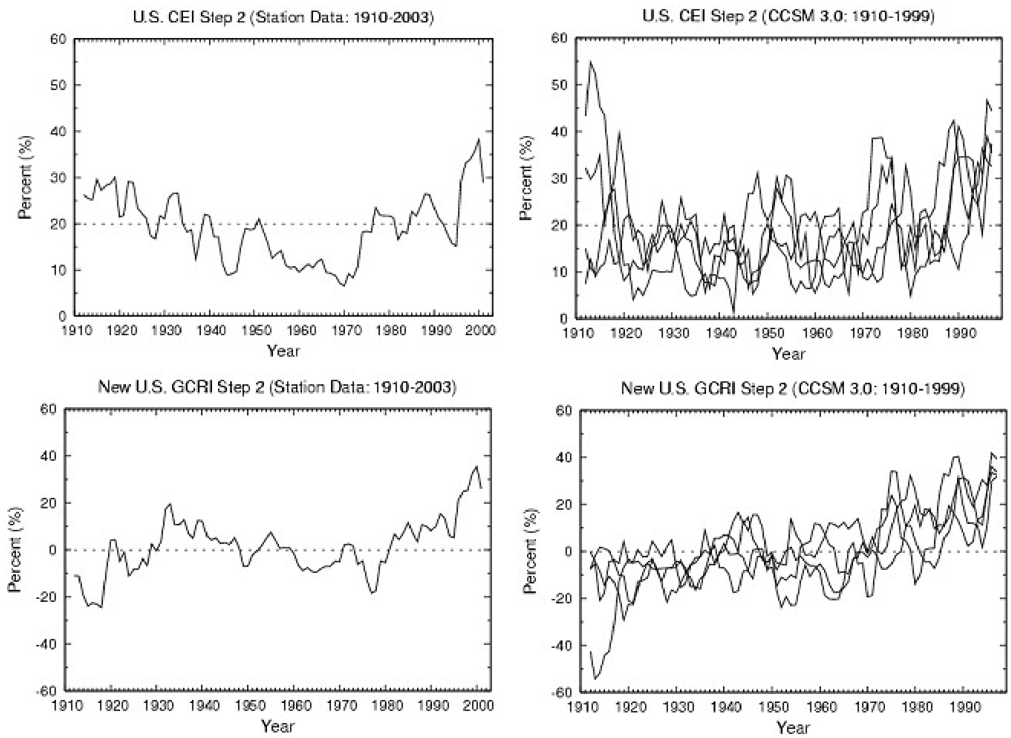
Karl et al. (1996) developed two indices to quantify observed changes in climate within the contiguous United States, a US Climate Extremes Index (CEI) and a US Greenhouse Climate Response Index (GCRI). The CEI is based on a combination of climate extreme indicators, while the GCRI is a combination of indicators based on projected changes due to greenhouse climate change. These indices integrate changes in climate over several different temperature and precipitation measures and are likely to provide early detection of important changes in climate in the United States. The CEI is used for operational climate monitoring at NCDC.

An assessment of variations of the CEI and GCRI over the twentieth century has been undertaken, including comparison of the observed indices with those calculated from global climate model simulations. Some issues with the operational calculation of the CEI at NCDC and interpretation of variations in the CEI have been identified. Some modifications to the operational algorithm are being implemented at NCDC. A new version of the GCRI has been developed. Significant increasing trends have been found in the components of the GCRI associated with extreme monthly-mean maximum and minimum temperatures, due to fewer cold extremes and more hot extremes across the continental US. These variations are outside the range of internal climate variations simulated by climate models and are consistent with the climate models' responses to increasing greenhouses gases and sulfate aerosols. Hence, it is likely that anthropogenic climate forcing is contributing to changes in temperature extremes in the United States. While there have been recent changes in the components of the CEI and GCRI associated with precipitation extremes, these are not outside the range of internal climate variations simulated by the climate models.

This project is ongoing.

Publications

Ruppert, A., and D. Karoly, 2005: Evaluation of climate model simulations of US climate indices. *CLIVAR IPCC AR4 Climate Model Simulations Analysis Workshop*, Honolulu, HI.



Top: CEI step 2 (sum of the percent area of the US with much above normal annual minimum temperature plus percent area of the US with much below normal annual minimum temperature) from observational data for 1910-2003 (left) and NCAR CCSM climate model simulations for 1910-1999 (4 different ensemble members) (right). Bottom: New GCRI (difference of the percent area of the US with much above normal annual minimum temperature minus percent area of the US with much below normal annual minimum temperature) from observational data for 1910-2003 (left) and NCAR CCSM climate model simulations for 1910-1999 (4 different ensemble members) (right). The increasing trend in the new GCRI indicates a reduction in cold extremes and an increase in warm extremes of annual minimum temperatures in both the observations and the climate model simulations. The definition of the CEI means that this appears as high values early in the period (many cold extremes) and high values at the end of the period (many hot extremes), leading to a U shape in the CEI.

Development and Application of Dynamic Normals for Investigation of Climate Variation and Change

Richman (primary – OU School of Meteorology)**, Lamb, Hamm**

NOAA Strategic Goal 2 *(Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond)*

Funding Agency: CIMMS Task III – NOAA/NESDIS/NCDC

Objectives

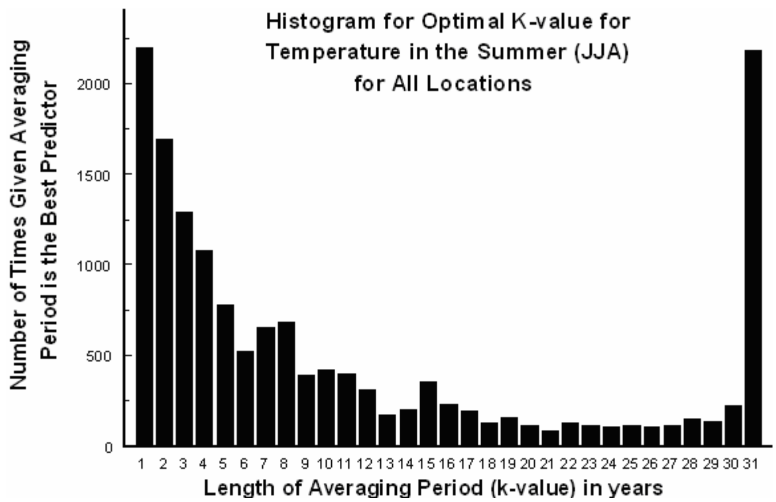
Use of dynamic normals to investigate climate variation and change.

Accomplishments

Dynamic normals differ from the standard climate normals in two ways: (1) using an "optimal" averaging period, instead of the standard 30 year averaging period and (2) utilizing the vast quantity of model-generated future climate data to further refine the normal. By employing these dynamic climate normals as long-range forecasts that can be verified, the optimal length averaging period (for a given location, season, and meteorological variable) can be determined which adds an important tool for climate outlooks and detecting climate change.

A literature review of past and current methodologies employed for optimal and dynamic normals began with the frequency method used by Lamb (1981) “On the ‘best’ temperature and precipitation normals: The Illinois situation.” The frequency method provides absolute values for determining the optimal length averaging period; however, confidence intervals must be applied to these results to determine their statistical significance. An efficient and accurate method to create such intervals is through the bootstrap. Other methods will also be used, including the investigation of correlations between forecast anomalies and observed anomalies (with respect to the standard 30 year climate normal) and the method of finding the minimum mean square error. Based on previous work, it is expected that different length averaging periods will be optimal in different parts of the country, in different seasons, and among different meteorological variables; however, regional consistency is likely and the identification of such regions is important for forecasts and the ability to detect climate change.

This project is ongoing.



Histogram for optimal I-value for temperature during June, July, and August.

Integration of Weather System Variability to Multidecadal Regional Climate Change: West African Soudano-Sahel Zone (1951-98)

Bell, Lamb (primary – CIMMS at OU)

NOAA Strategic Goal 2 *(Understand Climate Variability and Change to Enhance Society’s Ability to Plan and Respond)*

Funding Agency: CIMMS Task III – NWS International Activities Office

Objectives

Analyze a large set of daily rainfall data to relate disturbance lines and regional climate variability on intraseasonal-to-multidecadal timescales for 1951-98.

Accomplishments

Since the late 1960s, the West African Soudano-Sahel zone (10°-18°N) has experienced persistent and often severe drought that is among the most undisputed and largest regional climate changes in the last half-century. Previous documentation of the drought generally has used monthly, seasonal, and annual rainfall totals and departures, in a narrow “climate” approach that overlooks the underlying weather system variability. Most Soudano-Sahel rainfall occurs during June-September and is delivered by westward propagating, linear-type, mesoscale convective systems (Disturbance Lines, DLs) that typically have much longer north-south (10^2-10^3 km) than east-west (10-10^2 km) dimensions. Here, we analyze a large set of daily rainfall data to relate DL and regional climate variability on intraseasonal-to-multidecadal timescales for 1951-98. Raingauge-based indices of DL frequency, size, and intensity are evaluated on a daily basis for four 440 km square "catchments" that extend across most of the West African Soudano-Sahel (18°W-4°E), and then are distilled into 1951-98 time series of 10-day and seasonal frequency/magnitude summary statistics. This approach is validated using TAMSAT satellite IR cold cloud duration statistics for the same 1995-98 DLs.

Results obtained for all four catchments are remarkably similar on each timescale. Long-term (1951-98) average DL size/organization increases monotonically from early June through late August, and then decreases strongly during September. In contrast, average DL intensity maximizes 10-30 days earlier than DL size/organization and is more symmetrically distributed within the rainy season for all catchments except the westernmost, where DL intensity tracks size/organization very closely. Intraseasonal and interannual DL variability are documented using sets of very deficient (8) and much more abundant (7) rainy seasons during 1951-98. The predominant mode of rainfall extremes involves near season-long suppression or enhancement of the seasonal cycles of DL size/organization and intensity, especially during the late July-late August rainy season peak. Some other extreme seasons result only from peak season anomalies. On the multidecadal scale, the dramatic decline in seasonal rainfall totals from the early 1950s through the mid-1980s is shown to result from pronounced downtrends in DL size/organization and intensity. Surprisingly, this DL shrinking/fragmentation/weakening is not accompanied by increases in catchment rainless days (i.e., total DL absence). Like the seasonal rainfall totals, DL size/organization and intensity increase slightly after the mid-1980s.

This project has been completed.

Publications

Bell, M. A., and P. J. Lamb, 2005: Integration of weather system variability to multidecadal regional climate change: West African Soudano-Sahel zone, 1951-98. *J. Climate*, submitted.

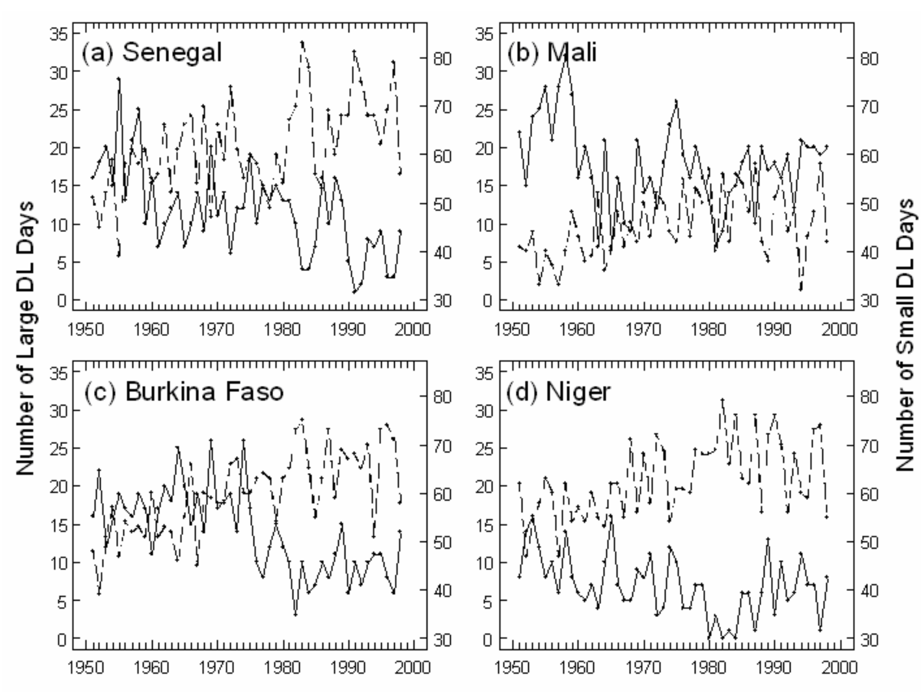


Fig. 12

Time series (1951-98) of June–September seasonal frequency of large/well-organized DLs (number of days per season DDEI ≥ 70%, solid line, left ordinate) and small/poorly organized DLs (number of days per season 0% < DDEI ≤ 30%, broken line, right ordinate) for (a) Senegal, (b) Mali, (c) Burkina Faso, and (d) Niger catchments.

Systems Integration and Prototype COOP Operations Management

Lamb, R. McPherson, Essenberg (primary – CIMMS at NERON)

NOAA Strategic Goal 2 *(Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond)*

Funding Agency: CIMMS Task III – NOAA/NWS OST

Objectives

Research the integration of climate observing stations and communications systems for COOP modernization with the prototype operations and monitoring component; investigate solutions to problems or limitations in previous climate observing networks so as to provide advice to the NWS regarding the 'state-of-the-art' in observing systems technologies.

Accomplishments

Based on research of other surface observing networks' configurations and maintenance procedures, with emphasis on those used by the Oklahoma Mesonet and the US Climate Reference Network, the Site Installation Plan and 8 revisions, the Site Maintenance Plan and 3 revisions, and a revision of the Plan Functional Requirements Document were completed for NOAA's Environmental Real-time Observation Network (NERON), which is the new name for the modernization of the Cooperative Observer Network. In addition, the NERON Site Survey Instructions document and its accompanying paper and electronic site survey forms were revised in cooperation with people at NWS, the Oklahoma Climatological Survey, and NCDC.

As part of the effort to meet the objectives of the project, two prototype NERON stations were installed during spring of 2005 for testing new sensors, equipment, and data logger software and for developing installation and maintenance procedures at the University of Oklahoma test bed on Max Westheimer Airport. During a Summer 2005 meeting with representatives of NWS and NCDC, consensus was reached on the hardware configuration for NERON sites, and the prototype stations are due to be upgraded for testing that configuration between Fall 2005 and Spring 2006.

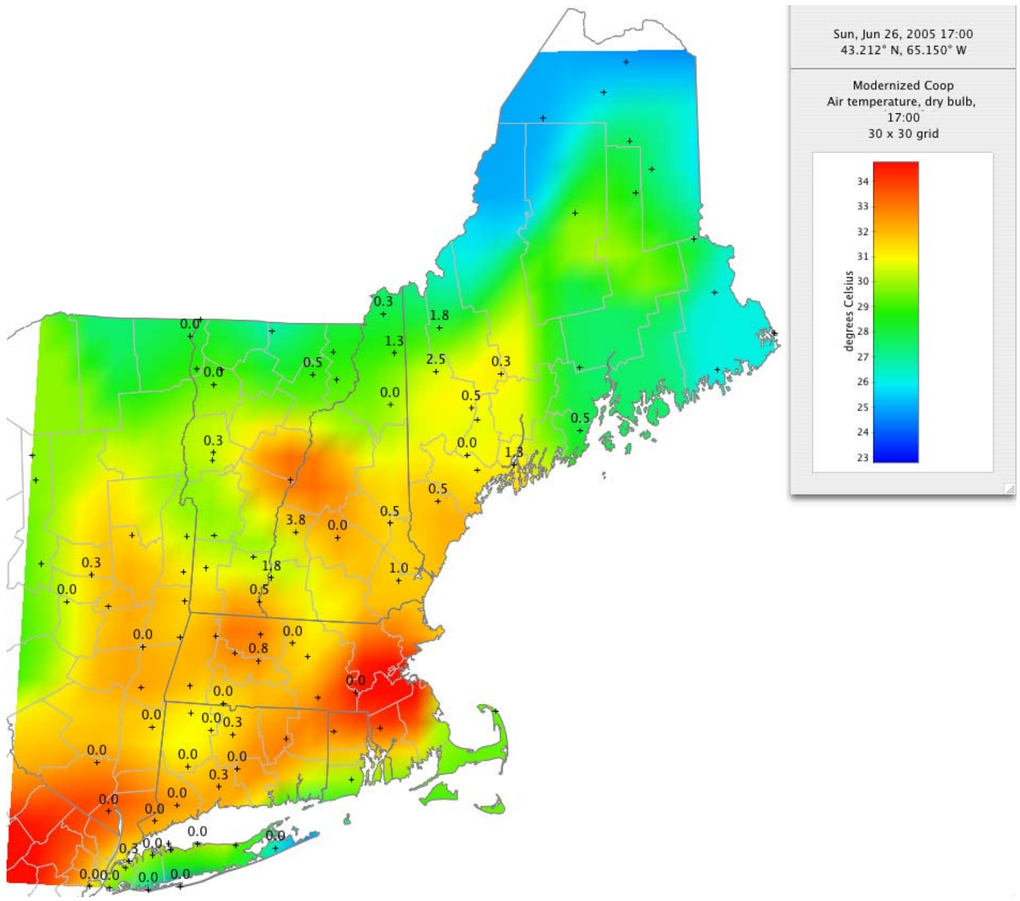
Work was completed in cooperation with the Oklahoma Climatological Survey to: (1) define how the prototype NERON metadata database should be structured and how its web interface should be designed; (2) find, acquire, configure, and test equipment for prototype VHF and 900 MHz radio telemetry systems with encryption capability meeting the requirements of the US Criminal Justice Information System Security Policy for deployment at law enforcement offices, which will allow two-way communication between NERON stations and the NERON Operations and Monitoring System (NOMS); and (3) define the structure and content of the proposed NERON web site, which serves as a real-time data distribution tool to NERON station site hosts. The metadata database and web site became operational during spring 2005 as part of the prototype NOMS set up and run by the Oklahoma Climatological Survey. The radio communication system has been installed and is operating in a test mode between the two prototype NERON stations and the NOMS. By the end of June 2005, NOMS was ingesting data from 101 NERON stations installed in New England and eastern New York.

This project is ongoing.

Publications

Crawford, K., S. Pritchett, T. Ross, and G. Essenberg, 2005: COOP Modernization: Building NOAA's Environmental Real-time Observation Network. *15th Conf. on Appl. Climatology*, Savannah, GA, Amer. Meteor. Soc., KS1.2, PDF.

Fiebrich, C. A., D. L. Grimsley, R. A. McPherson, K. A. Kesler, and G. R. Essenberg, 2005: The value of routine site visits in managing and maintaining quality data from the Oklahoma Mesonet. *J. Atmos. Oceanic Technol.*, in press.



Plot showing New England NERON air temperature and precipitation data at 1700 UTC on 26 June 2005. Station locations are indicated by crosses and the numerical values shown above station locations are precipitation in millimeters recorded since midnight local time. The temperature data indicate a sea breeze blowing inland across Long Island. The automated QA system flagged the temperature data from the stations on the south side of Long Island as bad due to the large difference in temperature but manual QA confirmed that the data were valid.

Prototype a Modernization Data Ingest and Quality Assurance System for a National Surface Mesonetwork

R. McPherson (primary – Oklahoma Climatological Survey), Wolfinbarger, Fiebrich

NOAA Strategic Goal 2 *(Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond)*

Funding Agency: CIMMS Task III – NOAA/NWS OST

Objectives

Adapt the Oklahoma Climatological Survey's (OCS) sophisticated, end-to-end procedures to prototype a data ingest and quality assurance system for multi-sensor, multi-network surface observations, including the modernized NWS COOP network. This end-to-end system was patterned after that now used by the Oklahoma Mesonet, thus taking advantage of the knowledge and experience gained during the past decade of its operation.

Accomplishments

OCS completed the first phase of work for the modernized cooperative observer (COOP) network from August 1 to December 31, 2004, with a no-cost extension through February 28, 2005. This project was expected to establish an infrastructure required for continued research on climate change monitoring and detection. It included the following components necessary to fulfill the proposed scientific research:

- A plan for full implementation of an Operations and Monitoring Center;
- A web site with access to the metadata necessary for scientists to study quality assurance techniques, both automated and manual;
- A web site with access to nationwide surface observations that are quality assured in near real-time; and
- A quantitative analysis of different rain gauges with respect to potential deployment across different climate regimes.

Work completed during Phase 1 included the following items:

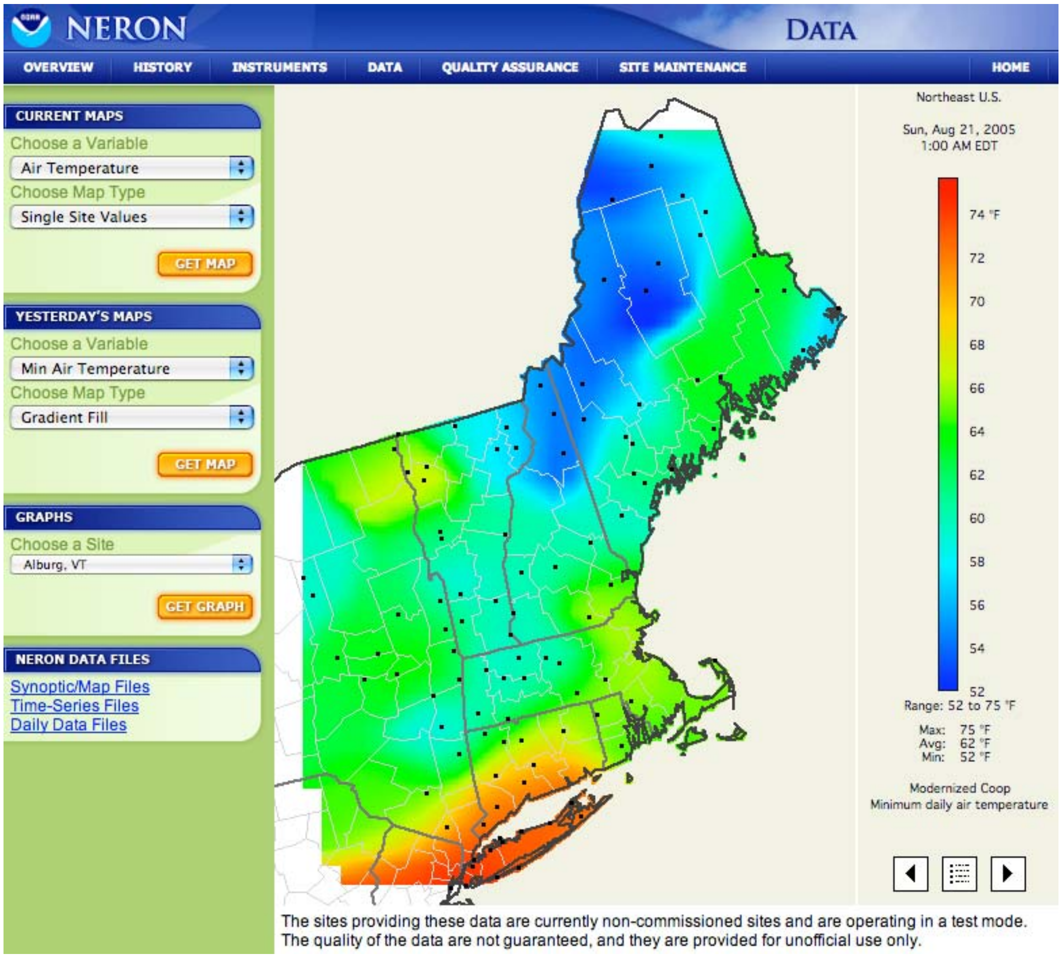
1. Setup and operation of data processing, database, and web servers in preparation for prototype activities for the modernized COOP;
2. Adaptation of Oklahoma Mesonet ingest, quality assurance, product generation, and metadata database software for application to the modernized COOP network;
3. Automated ingest of all modernized COOP station data from HADS and Prism data streams;
4. Automated quality assurance performed in real-time for all modernized COOP stations with accurate latitude/longitude/elevations;
5. Automated data file generation in real-time for all modernized COOP stations with accurate latitude/longitude/elevations;
6. Training of system administrator to begin data ingest handoff from Prism to OCS;
7. Prototype adaptation of Prism data ingest interface (converted from Access to MySQL);
8. Student data entry of all site survey forms from New England for incorporation into metadata database;
9. Organization of site survey metadata on a web page with site photos to assist in site selection (project delayed temporarily for NWS request to put New England data online);
10. Prototype development of an instrumentation database to track modernized COOP sensor locations, sensor inventories, station trouble tickets, station metadata, sensor calibration coefficients, and manual quality assurance flags (in progress and ongoing);
11. Prototype development of a New England Coop website (http://www.isos.noaa.gov; see attachment entitled "NERON Web Site Development");
12. Support for modernized COOP datasets in OCS's WxScope Plugin and WeatherScope display software (downloadable at http://sdg.ocs.ou.edu);
13. Daily reports of quality assurance metrics (both automated and manual) across the New England COOP made available through an online MySQL database;
14. Daily reports of station door flag status and battery voltage problems;
15. Regular reports of sites that are not reporting and variables that are flagged manually as erroneous;
16. Field study and quantitative assessment of TB3 rain gauges (see attachment entitled "Quantitative Analysis of the Performance of the Hydrological Services TB3 Rain Gauge");
17. Documentation of an implementation plan for a fully functional NERON Operations and Monitoring Center (see attachment entitled "Implementation Plan for the NERON Operations and Monitoring Center");
18. Consultation regarding the following sensor issues: Apogee IRT skin temperature sensor, Ott Pluvio weighing bucket rain gauge, use of heated tipping bucket rain gauges and their impact on weather station power budgets; standards accepted by various organizations (e.g., WMO, AASC) with regard to sensor installation heights;
19. Consultation regarding the following station issues: metadata "best practices;" station power budget calculations and solar power array sizing; station enclosure manufacturers and features; weather station maintenance practices at the major networks across the U.S.; skill sets for maintenance contractors; financial cost and time estimates, including detailed cost metrics, for station maintenance in the modernized COOP; strategies for site installations with shallow bedrock in New England; site survey instructions, forms, and required metadata for sites beyond New England; electronic servicing equipment required for COOP maintenance;

20. Consultation regarding the following datalogger issues: logger calibrations; pros and cons of various datalogger types and manufacturers with regard to programming, sensor inputs, etc;
21. Consultation regarding the following communications issues: data communications and encryption; locations (street address or latitude/longitude) of Law Enforcement Telecommunications System (LETS) offices in New England; LETS interfacing and access to data streams by third party network operators; wording for NWS-LETS memorandum of understanding; various communication systems (Airlink, Freewave, CSI, Maxstream, Kantronics); 900 MHz/VHF communications testing; short-range data transmission for manually inputted data (CSI RF400 900MHz vs. HPF-105 Bluetooth) from COOP observers;
22. Analysis of automated quality control methods and tests for surface observing networks;
23. Analysis of manual and automated quality assurance statistics from the Oklahoma Mesonet and their impact on 'the data quality problem' in the current cooperative observer network; and
24. WxScope Plugin, WeatherScope, and web site maintenance and support for prototype activities.

This project is ongoing.

Publications

Fiebrich, C.A., R. A. McPherson, C. C. Fain, J. R. Henslee, and P. D. Hurlbut, 2005: An End-to-End Quality Assurance System for the Modernized Coop Network. *15th Conf. on Applied Climatology,* Amer. Meteor. Soc, Savannah, GA, PDF.



Minimum daily air temperature map for the modernized COOP (aka NERON) in New England (from isos.noaa.gov). Dots indicate the location of NERON sites.

GIS-Based Selection of Potential National Weather Service COOP Sites: A Pilot Study in Maine, New Hampshire, and Vermont

Yuan, W. McPherson (primary – OU Center for Spatial Analysis), Rush, Rich

NOAA Strategic Goal 2 *(Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond)*

Funding Agency: CIMMS Task III – NOAA/NWS OST

Objectives

Formulate the COOP site selection problem in a GIS framework to derive a systematic and formal approach to determine areas of potential COOP sites; evaluate identified potential COOP sites in a geographic context to derive rankings of suitability among these sites; test the GIS methods in Maine, New Hampshire, and Vermont in response to the immediate needs of the three states. The GIS methods and deliverables may be refined later.

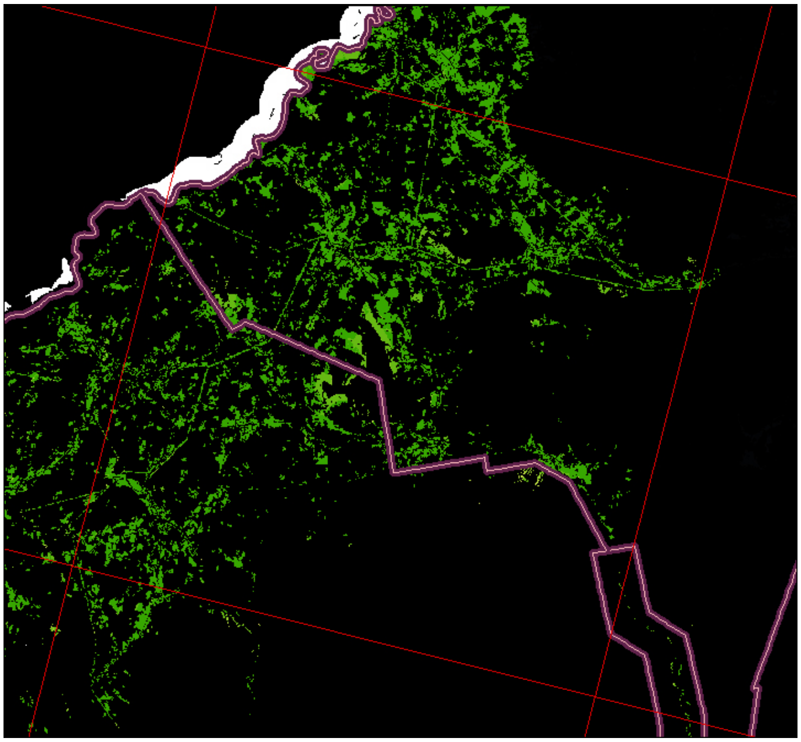
Accomplishments

We researched the steps involved in producing a model for site selection based on multiple criteria. Criteria included terrain, water, roads, airports, existing COOP stations, ASOS stations, police stations, and land use/land cover. Data included digital aerial photography, digital terrain models, and GIS layers acquired from state and federal databases. The model was designed and the output demonstrates the suitability of any given location for siting an automated COOP station.

This project has been completed.

Publications

McPherson, W. G. Jr., M. Yuan, D. Giuliano, K. Tapp, and J. Rush, 2005: Siting New England: a GIS prototype for site selection for the NWS Modernized Cooperative Network. CD-ROM, *Ninth Symp. on Integrated Observing and Assimilation Systems for the Atmosphere, Oceans, and Land Surface (IOAS-AOLS)*, San Diego, CA, Amer. Meteor. Soc.



Suitability layer for a given grid cell in New Hampshire.

Field Surveys for COOP and LETS Locations in New England

Yuan, W. McPherson (primary – OU Center for Spatial Analysis), Tapp, Giuliano, Rush

NOAA Strategic Goal 2 *(Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond)*

Funding Agency: CIMMS Task III – NOAA/NWS OST

Objectives

Test the GIS approach using field surveys.

Accomplishments

To test the GIS techniques being researched, a new field-survey approach to verification of station recommendations was examined. The field-survey techniques differed from existing methods used by the NWS in New England in a number of ways: (1) many of the initial field surveys resulted from objective data analysis rather than prior subjective site selection criteria (e.g., affability of a current landowner even if the location does not meet standards), (2) high-resolution geo-positioning, and (3) inclusion of the needs of automated stations (e.g., solar power requirements, radio transmission requirements) in the recommendations for the appropriateness of the station location. The field survey team interacted directly with the GIS team at OU to provide feedback as to what GIS techniques were most helpful and meaningful for site selection and what techniques required further research. More than 100 sites were surveyed in New England, including several legacy COOP stations.

This project has been completed.

Publications

McPherson, W. G. Jr., M. Yuan, D. Giuliano, K. Tapp, and J. Rush, 2005: Siting New England: a GIS prototype for site selection for the NWS Modernized Cooperative Network. CD-ROM, *Ninth Symp. on Integrated Observing and Assimilation Systems for the Atmosphere, Oceans, and Land Surface (IOAS-AOLS)*, San Diego, CA, Amer. Meteor. Soc.

Picture taken during a site survey of a legacy COOP station to determine if the site was suitable for upgrade.

Development of a Comprehensive GIS Model to Prototype a New National Weather Service COOP Network

Yuan, W. McPherson (primary – OU Center for Spatial Analysis), Roberson, Rush, Walsh

NOAA Strategic Goal 2 *(Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond)*

Funding Agency: CIMMS Task III – NOAA/NWS OST

Objectives

Revise the GIS method based on lessons learned from the three New England states, the different geographic context in each state, and additional variables to be considered (e.g., solar incidence), and incorporate the COOP requirements and national, regional, and local needs in a multi-scalar, multi-criteria methodological framework; for each of the states, analyze potential COOP sites to illustrate the geographic context at each site and determine rankings among these sites based on their qualifications to COOP specifications and proximity to existing related infrastructure (e.g., accessibility, airport facility, etc.); and expand current research activities at the University of Oklahoma, especially in the representation of dynamic geographic phenomena in support of spatio-temporal query, analysis, and modeling.

Accomplishments

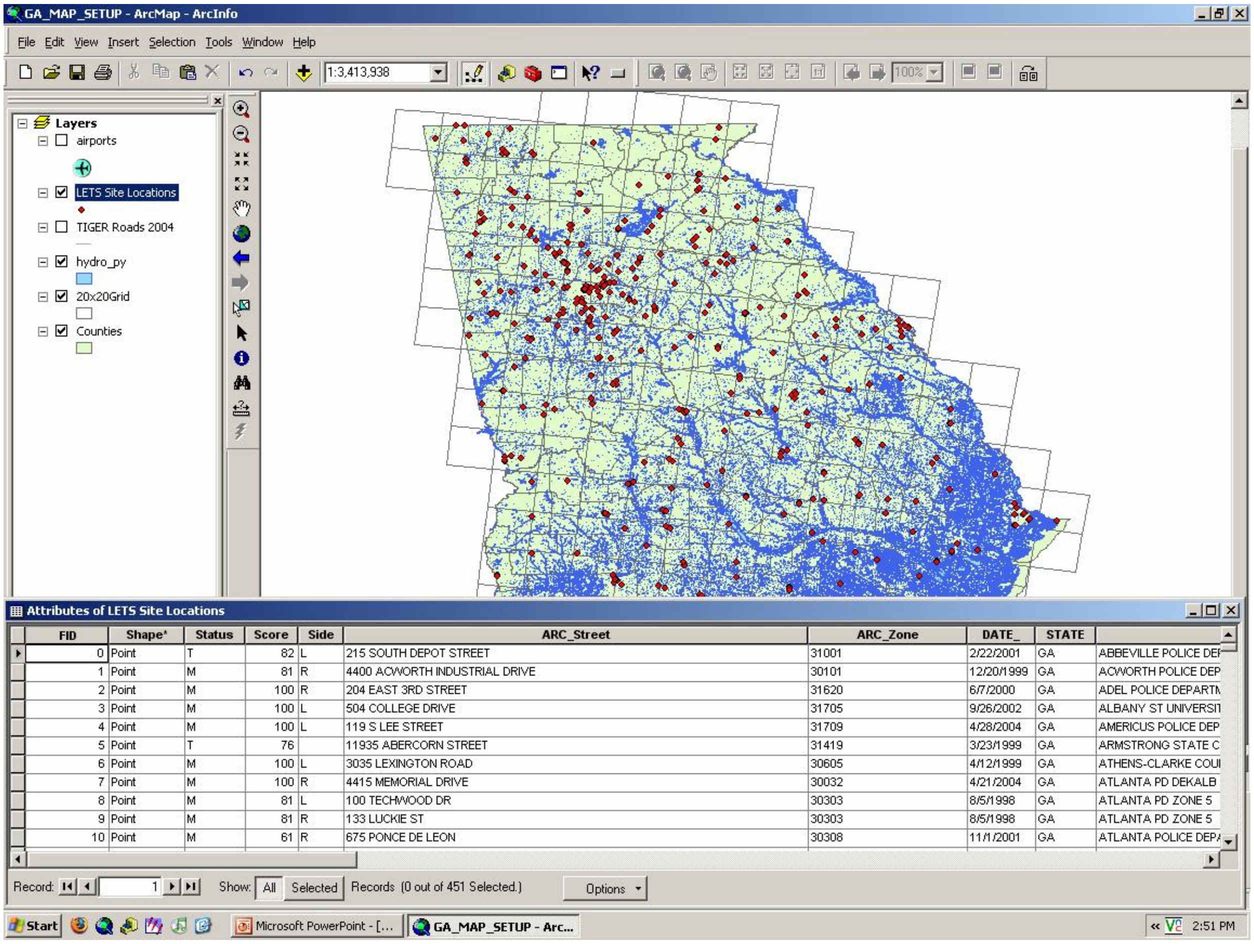
This project builds upon the previous modeling effort and the experience gained through the surveys. It also expanded the region to analyze to the rest of New England (beyond ME, NH, and VT) and into the southeastern U.S. In addition, the GIS work included analysis of existing state networks (e.g., Georgia Mesonet) and their usefulness to a modernized COOP. Also, after geo-coding locations of the Law Enforcement Telecommunications System (LETS) agencies, techniques were examined for determining line-of-sight for radio linkage from a potential COOP station to a nearby LETS agency to test a different communications method rather than the currently used CDMA or GOES linkages.

Based on the GIS analysis, we recommended two or three potential sites in a given COOP grid cell. If the GIS model eliminated too much area to find an acceptable site, then we backed off some layer criteria to see if an adequate site could be found in the grid cell. Final site selection was not made from remote analysis alone; a site survey was conducted by a local, trained official to ensure its final suitability for site installation.

This project is ongoing.

Publications

McPherson, W. G. Jr., and M. Yuan, 2005: A GIS approach to site selection for the NWS Modernized Cooperative Network. *15th Conf. on Applied Climatology and 13th Symp. on Meteorological Observations and Instrumentation*, Savannah, GA, Amer. Meteor. Soc.



Example of geocoding of LETS locations in preparation for line-of-sight analysis in Georgia

Investigation of Synoptic and Mesoscale Meteorological Processes Associated with Hazardous Weather – *Climatology of Drizzle in the United States and Canada*

Schultz (primary – CIMMS at NSSL)**,** Sears-Collins, Johns

NOAA Strategic Goal 2 *(Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond)*

Funding Agency: CIMMS Task II – NSSL Project 6

Objectives

Construct a climatology of drizzle occurrence in the United States and Canada.

Accomplishments

One of the major challenges in GCMs is adequately simulating the diurnal patterns of the occurrence, frequency, and intensity of these light precipitation events. Increased understanding of such patterns can potentially improve the distribution and temporal variation of atmospheric cloudiness, the radiation balance, and surface temperature variations in GCMs. One program, the NCAR Water Cycle Across Scales initiative, examines the diurnal cycle of precipitation as a means of improving forecasts of large-scale precipitation changes in GCMs. Despite the importance of drizzle to climate modeling, little information exists about its observed spatial and temporal variability across the U.S. and Canada. This research aims to provide high-resolution maps of the drizzle climatology.

A 15-year climatology of drizzle is constructed from 584 stations across the United States and Canada. Forty percent of the stations have a drizzle maximum from November to January, whereas only 13% of stations have a drizzle maximum from June to August. Drizzle occurrence possesses a seasonal migration from eastern Canada and the central portion of the Northwest Territories in summer, equatorward to most of the eastern United States and southeast Canada in early winter, to southeastern Texas and the eastern United States in late winter, and eastern Canada in the spring. The hourly frequency of drizzle increases sharply from 0900 UTC to 1200 UTC, followed by a steady decline from 1300 UTC to 2300 UTC.

This project is ongoing.

Publications

Sears-Collins, A. L., D. M. Schultz, and R. H. Johns, 2005: The spatial and temporal variability of drizzle in the United States and Canada. *J. Climate*, submitted.

Burke, P. C., and D. M. Schultz, 2004: A four-year climatology of cold-season bow-echoes over the continental United States. *Wea. Forecasting*, **19**, 1061-1074.

ARM Program Data Quality Office

Peppler (primary – CIMMS at OU), **Kehoe, Sonntag**, Moore, Hughes, Doty, **Shafer, Burkholder**, **T. Thompson, Hiers, Zaman, Farmer**

NOAA Strategic Goal 2 *(Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond)*

Funding Agency: Pacific Northwest National Laboratory

Objectives

Inspect, assess, and report on U.S. DOE ARM data from the Southern Great Plains, Tropical Western Pacific, and North Slope of Alaska sites on a near real-time basis, develop the tools necessary to conduct the activity, and provide support to site operators, site scientists, and instrument mentors to solve instrument measurement problems.

Accomplishments

The Atmospheric Radiation Measurement (ARM) Program Data Quality Office was formed in July 2000 to coordinate the data quality activities of the ARM Program, in response to a program review in 1999 identifying such a need. The ARM Program fields instrumentation and collects data from Climate Research Facilities located in the U.S. Southern Great Plains, North Slope of Alaska, and Tropical Western Pacific. These data are used by ARM scientists to learn more about the climate system and to apply this knowledge to improve the treatment of clouds and atmospheric radiation in climate models. Thus, to support the research properly, the data the ARM Program collects must be of high quality.

The Data Quality Office is responsible for making sure that ARM data are usable, so that data users are able to readily determine whether the data have been reviewed, how they were reviewed, and whether there are known problems. To facilitate this process, the Data Quality Office has developed a web-based tool called the Data Quality Health and Status (DQ HandS) system (http://dq.arm.gov/). DQ HandS reads ARM data files, displays flag information in the form of color tables, provides pop-up information indicating the nature of the flags violated, produces diagnostic plots of key parameters and allows for the interactive plotting of any file variables, and hosts various assessment and problem reporting mechanisms.

Among recent improvements and additions to DQ HandS are: incorporation of more ARM datastreams, including those from eddy correlation systems and radar wind profilers; inclusion of ARM Mobile Facility data during its initial deployment at Point Reyes, CA; a new thumbnail plot browser to facilitate the viewing of a string of diagnostic plots for trends; an improved method for writing and databasing weekly data quality assessment reports; and an improved method for searching ARM report databases for determining problem context. The Data Quality Office is participating in ARM-wide discussions on new ideas for how to include more automated quality control information within ARM data files and ways to incorporate the results of value-added product processing within the routine data quality process.

This project is ongoing.

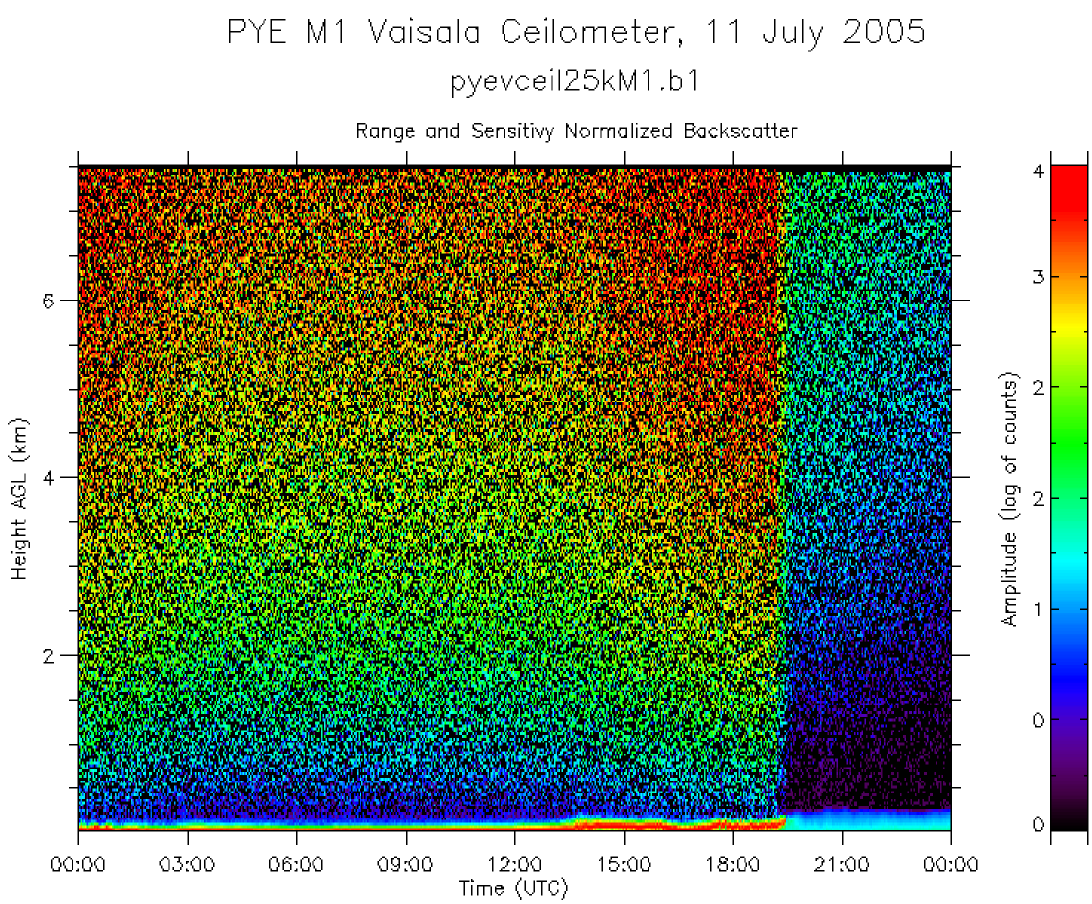
Publications

Kehoe, K., K. Sonntag, R. Peppler, B. Burkholder, C. Shafer, M. Zaman, T. Thompson, S. Moore, G. Hughes, and K. Doty, 2005: Improvements to and status of the Data Quality Health and Status (DQ HandS) System. Proc.,*15th ARM Science Team Meeting*, Daytona Beach, FL, U.S. Dept. of Energy, http://www.arm.gov/publications/proceedings/conf15/extended_abs/kehoe_k.pdf.

Mace, G.G., S. Benson, K.L. Sonntag, S. Kato, Q. Min, P. Minnis, C.H. Twohy, M. Poellet, X. Dong, C. Long, Q. Zhang, and D.R. Doelling, 2005: Cloud radiative forcing at the ARM Climate Research Facility: Part 1. Technique, validation and comparison to satellite-derived diagnostic quantities. *J. Geophys. Res.*, in press.

Peppler, R.A., K.E. Kehoe, K.L. Sonntag, S.T. Moore, and K.J. Doty, 2005: Improvements to and status of ARM's Data Quality Health and Status System. *15th Conf. on Applied Climatology*, Savannah, GA, Amer. Meteor. Soc., J3.13, http://ams.confex.com/ams/pdfpapers/91618.pdf.

Sonntag, K.L., 2004: Linking the Large Scale Dynamics and Cloud Radiative Forcing: The March 2000 Intensive Observational Period. M.S. thesis, Dept. of Meteorology, University of Utah, 145 pp.



Backscatter from Vaisala ceilometer located at the Point Reyes, CA, ARM Mobile Facility on 11 July 2005 showing very low, thin stratus and fog.

ARM Program Southern Great Plains Site Scientist Team

Lamb (primary – CIMMS at OU)**, Bond, Groff**

NOAA Strategic Goal 2 *(Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond)*

Funding Agency: U.S. DOE

Objectives

Provide scientific support for Southern Great Plains site operations, conduct a site-relevant research program, and conduct educational outreach activities.

Accomplishments

The Southern Great Plains Site Scientist Team is responsible for three major areas of activity: provide on-site scientific expertise on a daily basis and support of data quality efforts in coordination with the Data Quality Office; conduct a research program focused on the SGP site data which furthers the goals of the overall ARM Program; and conduct an educational outreach program that exploits the availability of the SGP site and its data streams. See the "Public Affairs and Outreach" section below for an update on relevant outreach activities. The Site Scientist team continues to support and manage a weekly teleconference to coordinate site activities, with meeting minutes posted on the web.

The Site Scientist Team also participates in a number of specific activities as part of its mission to provide scientific oversight for the SGP locale. During the past year David Groff participated in the Continuous Quality Improvement Program (CQIP) tours during November-December 2004 and April 2005. These tours included stops at extended facilities, boundary facilities and intermediate facilities. The state of data wiring, instrument leveling and shadowing alignment were among several considerations when inspecting the various facilities. These inspections are important in maintaining data quality.

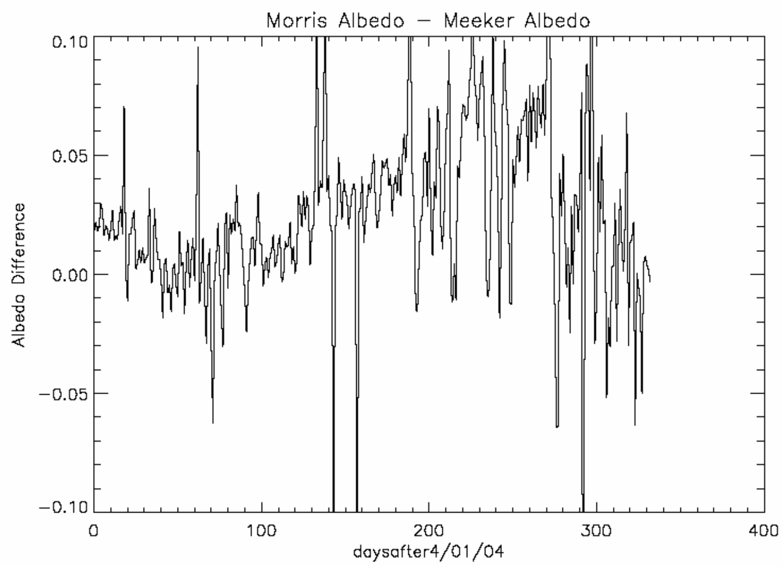
During 18-19 October 2004 cloud base height, cloud top height, optical depth estimates and optical depth forecasts were provided by David Groff to Lieutenant Andy Bowers in support of a flare detection project. Liquid water path measurements from the microwave radiometer were used to estimate optical depth. Aircraft flew over the Central Facility in Lamont to ascertain performance in detection of a surface flare for optical depths ranging between 5 and 20.

In support of ARM outreach David Groff gave a presentation to the Ponca City Aviation Boosters. A Lions Club presentation is given each fall in Ponca City as well.

An ongoing albedo study for ARM SGP extended facilities is being conducted by David Groff. This effort is in response to a question raised in a paper written by Claude Duchon (Professor of Meteorology at OU) and Ken Hamm (former graduate student at OU). Preliminary results suggest that the albedo at the Morris extended facility is anomalously high (see comparison to Meeker albedo in the figure below). To follow up on these results 7x7 m subsets of MODIS land products have been requested at 1 km resolution. The subsets will be centered on six sites with the most homogenous vegetation surfaces among those in the SGP domain.

In support of SGP data quality, code has been written to compare meteorological data from the SuomiNet and SMOS systems over a six month period.

This project is ongoing.



The difference between Morris, OK, and Meeker, OK, albedo.

ARM Program Soil Water and Temperature System Instrument Mentorship

Bond (CIMMS at OU)

NOAA Strategic Goal 2 *(Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond)*

Funding Agency: Argonne National Laboratory

Objectives

Monitor, report, and improve on the quality of data produced by the Soil Water and Temperature Systems (SWATS) installations located across south central Kansas and northern and central Oklahoma; serve as the technical contact for researchers and the public regarding SWATS.

Accomplishments

In addition to ARM infrastructure tasks related to reporting on the SWATS instrument and the data it produces, work has been performed to produce general statistical analysis of soil moisture and temperature data. Work is planned on the reinstallation of aging SWATS sensors.

This project is ongoing.

Publications

Bond, D.W., 2005: Soil water and temperature data. Proc., *15th ARM Science Team Meeting*, Daytona Beach, FL, U.S. Dept. of Energy.

Project Support for the Assimilation, Analysis and Dissemination of Pacific Rainfall Data - PACRAIN

Morrissey (primary – OU School of Meteorology), Postawko, Greene

NOAA Strategic Goal 2 *(Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond)*

Funding Agency: CIMMS Task III – NOAA OGP

Objectives

Support NOAA's Office of Global Program's (OGP) Climate Observation Element's mission to "build and sustain the global climate observing system that is needed to satisfy the long-term observational requirements of the operational forecast centers, international research programs, and major scientific assessments"; continue in our role as the Surface Reference Data Center (SRDC), a core program which supports the Global Precipitation Climatology Project (GPCP), by expanding our mission to collect, analyze, verify and disseminate global rainfall data sets and products deemed useful for Operational Forecast Centers, International Research Programs and individual researchers in their scientific endeavors.

Accomplishments

Rainfall data is particularly important in the tropics. Not only is it a tracer of latent heat, it is vitally important to the understanding of ocean properties as well, such as latent and sensible heat flux, salinity changes and attendant local ocean circulation changes. In addition, raingauge observations from low-lying atolls are required to conduct verification exercises of nearby buoy-mounted raingauges.

Housed in the Environmental Verification and Analysis Center (EVAC) at the University of Oklahoma, the EVAC/SRDC has built upon work from past NOAA-supported projects to become a unique location for scientists to obtain scarce raingauge data and to conduct research into verification activities. These data are continually analyzed to produce error-assessed rainfall products. Scientists need only to access the EVAC/SRDC web site http://www.evac.ou.edu/pacrain to obtain the most comprehensive Pacific rainfall data set anywhere and http://www.evac.ou.edu/srdc to obtain critical regional raingauge data sets. Many of these regional data sets are impossible to obtain elsewhere. The EVAC/SRDC serves the research community by actively working with individual countries in environmentally important locations to help provide them with infrastructure, education and other short and long-term support. The return on this investment by NOAA has been significant in terms of enabling EVAC/SRDC to provide the scientific community with critical, one-of-a-kind raingauge data sets and to have established ongoing mutually beneficial relationships which should lead to future collaborations. Past successes with this strategy have proven very worthwhile on a cost-benefit basis.

Due to the importance of tropical Pacific rainfall data to climate research and operational and climate forecasting we are intensifying our efforts by working collaboratively with the Pacific Island Global Climate Observing System (PI-GCOS) program to effectively and efficiently match the areas of commonality among both OGP's Climate Observations and PI-GCOS's objectives. One of these common areas is the strengthening of the existing Pacific observation climate networks for both atmosphere and ocean.

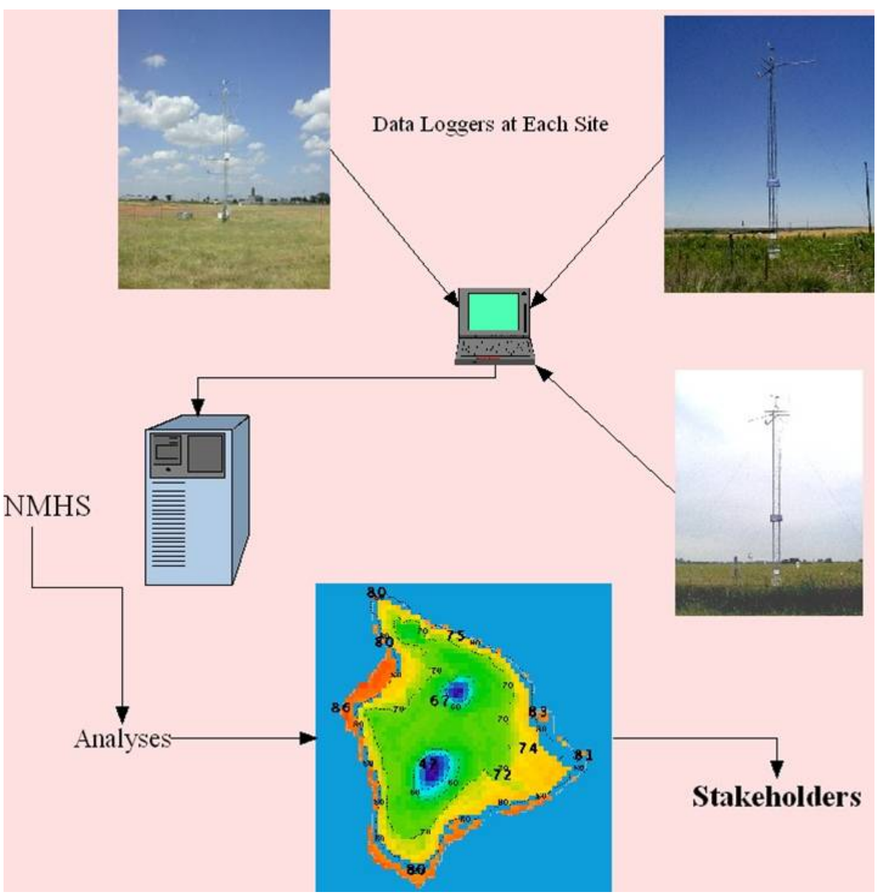
We are using the above strategy to expand our efforts to increase the raingauge climate observing data base representing specific, environmentally critical locations. It is not our intention to collect all raingauge data world-wide, but to assimilate raingauge data 1) in environmentally critical locations (e.g. tropical Pacific), 2) where dense raingauge networks exist and 3) where agreements can be made to help construct raingauge networks in these critical locations. An experimental effort focused on the latter objective with the government of Kiribati has resulted in a network of 15 new raingauges located on 15 atolls managed by the Kiribati Meteorological Service. In addition, similar pilot projects have produced a relatively dense raingauge network on the island of Niue in the south Pacific and a critical all weather observation platform on Pitcairn island in the south east Pacific. The success of these relatively low-cost efforts has motivated us to expand these pilot projects in collaboration with PI-GCOS to other Pacific Island locales.

It is our belief that by working directly with local Pacific Island meteorological services, we bring tangible benefits to the global climate research community through data base enhancement. In turn, the local meteorological services benefit directly through enhanced forecast products developed by the scientific community using these critical data sets.

To better accomplish these tasks, the Principal Investigator (i.e. P.I.) of this project took leave from his University of Oklahoma position to become the first PI-GCOS coordinator headquartered at the Secretariat for the Pacific Regional Environmental Program (i.e. SPREP) in Apia, Samoa. During his 1.5 year tenure there (from January 2004 through May 2005) he helped consolidate the PI-GCOS program by working with or initiating various high priority PI-GCOS projects outline in the PI-GCOS action plan. He coordinated the 10th Regional Meteorological Director's meeting hosted by the island nation of Niue and ran the 1st meeting of the PI-GCOS steering group. Since returning to the University of Oklahoma, the P.I. is working with the PI-GCOS program by focusing on building a sustainable basic climate instrument network in collaboration with the Pacific Island Meteorological Services. Currently, we are supplying the Pacific Island countries with high quality tipping bucket rain gauges complete with HOBO data loggers and running field experiments in the Pacific to test their accuracy and reliability.

In addition to the work above, we are completing and testing an experimental seasonal rainfall forecast method being developed using artificial intelligence methods, tropical Pacific rainfall and NOAA-produced sea surface temperature and 700 mb geopotential height data. It should be noted that without a good supporting rainfall database such a forecasting scheme could not be successful.

This project is ongoing.



Pacific Island Global Climate Observing System (PI-GCOS).

PUBLIC AFFAIRS AND OUTREACH

National Weather Center Research Experiences for Undergraduates Program

Zaras (primary – CIMMS at NSSL)**, Schultz, Heinselman, Kogan, Mechem, Murillo, Mejia, Lakshmanan, Forren, Smith, Stumpf, Schlatter, Mansell, Spencer, Kain, Baldwin, Elmore, Schuur, Scharfenberg, Brooks, Peppler, Sonntag, Dean,** Johns, Gonzalez-Espada, Grant, Hales

Funding Agency: NSF

Objectives

Provide college interns a unique summer research experience through participation in a research project, exploration of career options, and development of relevant skills and knowledge to become good practitioners and consumers of research.

Accomplishments

Through participation in the National Weather Center REU program, undergraduate students explored careers in atmospheric science research. The objective of the program is to provide students an opportunity to try research while building relevant skills and knowledge to become good practitioners and consumers of research. Each student collaborated with a science or team of scientists to conduct research and lived the life of a scientist through attending scientific lectures, participating in workshops to build skills and knowledge relevant to the job, participating in career exploration activities, learning and practicing a variety of research methods, and presenting their research in both written and oral formats.

Four ideas were experimented with in 2004-2005. First, one visiting faculty brought in to co-mentor a student, Dr. Wilson Gonzalez-Espada from Arkansas Tech University, worked out incredibly well. He assisted on at least five student projects, two of which were related to his specialty of science education, and two of which took advantage of his native language of Spanish. He formed collaborations with at least seven NWC scientists, resulting in two publications with an additional few likely. A second visiting co-mentor position was not filled due to lack of applications. Second, over one third of past students returned for the REUnion held in June 2005, taking full advantage to network within and across years and with mentors. It was both a morale booster and helped this year's participants truly envision making it to graduate school and interesting careers. Over sixty of 96 participants submitted information for the Directory to be published this fall. Third, the 2004 participants finally started to believe they were contributing to research after having interesting discussions when they presented their work to strangers at the American Meteorological Society's annual meeting. And, finally, full analysis is underway now that the second year of data collection of Career Journey Journals is complete. Student satisfaction is extremely high from this and many other programs, but why and how students come to clarity on graduate school and career decisions through these programs is unclear.

In addition to individual mentor scientists increasingly leading their students through projects that impact the broader meteorological community through formal publication, this program will contribute more broadly to understanding how and why students come to clarity on career direction.

This project is ongoing.

Publications

Zaras, D. S., 2005: Activities, Findings, and Recent Developments of the National Weather Center Research Experiences for Undergraduates Program. CD-ROM, *14th Symp. on Education*, San Diego, CA, Amer. Meteor. Soc., 2.3.

Sears-Collins, A. L., D. M. Schultz, and R. H. Johns, 2005: The spatial and temporal variability of drizzle in the United States and Canada. *J. Climate*, submitted.

Mazur, R., G. Stumpf, and V. Lakshmanan, 2004: Quality Control of Radar Data to Improve Mesocyclone Detection. CD-ROM, *20th International Conf. on Information Processing*, Seattle, WA, Amer. Meteor. Soc, P 1.2a.

Brooks, H. E., A. R. Anderson, K. Riemann, I. Ebbers, and H. Flachs, 2005: Climatological aspects of convective parameters from the NCAR/NCEP reanalysis. *Atmos. Res.*, in press.

Gonzalez-Espada, W. and D. S. Zaras, 2005: Evaluation of the Impact of the NWC REU program compared with other undergraduate research experiences. *J. Geoscience Edu.*, submitted.

Elmore, K. L. and A. J. Hamm, 2005: An examination of the NCEP SREF performance. *Wea. Forecasting*, submitted.

Metz, N. D., D. M. Schultz, and R. H. Johns, 2005: Extratropical cyclones with extra warm-front-like baroclinic zones and their relationship to severe weather. *Wea. Forecasting*, **19**, 907-916.

Van Den Broeke, M. S., D. M. Schultz, R. H. Johns, J. S. Evans, and J. E. Hales, 2005: Cloud-to-ground lightning production in strongly forced, low-instability convective lines associated with damaging winds. *Wea. Forecasting*, **20**, 517-530.

Hamm, A. J. and K. L. Elmore, 2004: A validation of the NCEP SREF. CD-ROM, *20th Conf. on Weather Analysis and Forecasting*, Seattle, WA, Amer. Meteor. Soc., 7.6.

Kalb, C. P., A. R. Dean, R. A. Peppler, and K. L. Sonntag, 2004: Intercomparison of cloud base height at the ARM Southern Great Plains site. Proc., *14th Atmospheric Radiation Measurement (ARM) Science Team Meeting*, Albuquerque, NM, U.S. Dept. of Energy, http://www.arm.gov/publications/proceedings/conf14/extended_abs/kalb_cp.pdf.

Dubois, J. A. and P. L. Spencer, 2005: Computing divergence from a surface network: Comparison of the triangle and pentagon methods. *Wea. Forecasting*, **20**, 596-608.

Verbout, S. M., L. M. Leslie, H. E. Brooks, D. Schultz, and D. Karoly, 2005: Tornado outbreaks associated with land-falling tropical cyclones in the Atlantic Basin. CD-ROM, *Sixth Conf. on Coastal Atmospheric and Oceanic Prediction and Processes*. San Diego, CA, Amer. Meteor. Soc., 7.1.

REU class of summer 2005.

ARM Program Outreach Activities

Kloesel (primary – OU College of Geosciences), Melvin

Funding Agency: U.S. DOE

Objectives

Provide outreach support for the ARM Program to K-12 teachers and students throughout Oklahoma, Kansas, and the U.S.

Accomplishments

ARM Program/SGP educational outreach activities during the fiscal year were marked most notably by the July 2005 EarthStorm workshop for K-12 teachers, the 12th Anniversary Mesonet/ARM Science Fair, and the Delta Education Weather and Water teacher workshop co-sponsored by the Full Option Science Series (FOSS) at the University of California at Berkeley. ARM/SGP Outreach staff presented papers or posters at the American Meteorological Society Annual Meeting in San Diego, CA; the National Science Teachers Association National Meeting in Dallas, TX; the Oklahoma Science Teachers Association State

Meeting in Oklahoma City, OK; and at regional and local teacher in-services and workshops throughout Oklahoma, Kansas and Texas.

The “Magic School Bus Kicks up a Storm” traveling children’s museum exhibit continues to tour the country entertaining over 2 million visitors annually. The exhibit is a joint effort between the Oklahoma Climatological Survey (OCS) and numerous other entities. ARM data are used heavily in the training of teachers and students so that they may get the most out of their field trip experience. OCS staff continues to train and provide consulting to personnel from each museum visited (8 per year). This exhibit will continue to tour North America through 2008.

For the sixth consecutive year, OCS Outreach presented a workshop for Kansas teachers at Emporia (KS) High School. The workshop provided scientific knowledge to help the Emporia teachers with an online environmental course. The online course provides teachers with increased scientific knowledge, infuses multidisciplinary concepts, promotes integration of technology into classrooms, and encourages teacher networking and peer mentoring. The OCS workshop covered all facets of measurements at the ARM SGP site and the Oklahoma Mesonet, remote sensing, Earth's seasons and its atmosphere, the electromagnetic spectrum, and global warming. Over the past five years, every student (~2,200) at Emporia High School has worked with ARM data in the classroom.

The ARM/SGP outreach staff and OCS “Storm Team” teacher-consultants traveled throughout Oklahoma and Kansas conducting workshops on how to use ARM and Oklahoma Mesonet data in the classroom. The workshops focused on the OCS Outreach web site and how to use the WxScope Plugin visualization software as well as the newly developed WeatherScope “stand-alone” application to display interactive maps and graphs. The popular short courses entitled “Mirror, Mirror on the Wall, Do Snow and White Reflect It All?” and “Thermodynamics of Pizza” were presented at 4 different in-service teacher workshops in Oklahoma. Evaluations from the teachers taking the short courses were unanimously positive. Teachers attending OCS short courses and summer programs will reach over 3000 students in 8 states this fall.

OCS/ARM SGP Outreach also conducted a workshop for engineering and remote sensing held in Mayaguez, Puerto Rico for K-12 teachers across North America. This workshop was held at no cost to the ARM program (funded by NSF), yet exposed 30 teachers from across North America (the U.S. and Caribbean) to ARM data and OCS on-line lessons that utilize ARM data. These teachers will reach another 1500 students in their schools this fall.

OCS continues work on its Weather Series. The Weather Series is a collection of educational activities intended for use with real-time or archived ARM and Mesonet data. There are two main components of the OCS Weather Series: reference materials and lessons. Teachers use the reference materials as refresher information prior to teaching a given subject. The OCS Weather Series lessons are aimed at the middle school grade level, but can be modified by the teacher to be more or less difficult. The lessons typically require environmental data and many can be used with recent or real-time data. The lessons contain a list of prerequisites for the activity, suggested grade levels, an overview of the lesson content, ideas for the teacher to apply the lesson, the experiment, and several questions. Each lesson is reviewed yearly and new data cases are added. OCS is now expanding these activities to a national focus and is completing work on a new web site to deliver these materials. A laboratory manual for undergraduate students taking meteorology classes, called Explorations in Meteorology, was completed and is now available from Brooks Cole Publishers. This lab manual makes use of ARM SGP data in its’ activities.

In addition, OCS/ARM SGP lessons continue to be a component of the Aurora Project GeogWeb. Aurora is a statewide educational project whose mission is to create an interactive collaborative learning community among teachers and students, homes and towns, and public and private organizations across Oklahoma. Aurora uses a geography-based curriculum full of real problems and relevant experiences to integrate several educational disciplines. Learning activities in GeogWeb take advantage of resources in local communities of Oklahoma. Aurora is funded by the U.S. Department of Education.

This project is ongoing.

Outreach Activities of CIMMS Staff at NSSL

Zaras, Tarp (primary – NOAA Weather Partners)**, and Staff**

Objectives

Inform an interested public in our research activities and how these activities impact their daily lives; share the task of outreach activities among many staff members, using their skills to best accomplish the task.

Accomplishments

Outreach activities performed during the past year include:

- The National Severe Storms Laboratory celebrated its 40th anniversary in October. The celebration included open houses for elementary school classes and for the general public, public lectures about the role of NSSL as a scientific organization, and a banquet that highlighted a new video about the history of the lab and its activities. The event received extensive local coverage. A number of NSSL staff and CIMMS staff working at NSSL participated in the planning and execution of the activities.
- Dave Schultz has been mentoring a high school student in Pennsylvania on a meteorology project. He co-advises two OU M.S. students and serves on the committee of another M.S. student. He also writes the Weather Watch column, that highlights NOAA and NSSL research, for Canoe & Kayak magazine. Dave Schultz gave a talk on winter storms of the western United States to the Oklahoma Ski Club and spoke about weather instruments to about 100 middle school students from the Classen School for Advanced Studies in Oklahoma City. Dave Schultz spoke at an OSLEP course about science communication, gave two talks at Cornell University about his research, spoke to undergraduate students at St. Cloud State College about his research and his role as a scientist, and gave a talk to the Exchange Club in Norman about his experience forecasting at the Winter Olympics in Salt Lake City. Dave Schultz gave talks to meteorology students at the University of Wisconsin at Madison and Milwaukee, Valparaiso University, Purdue University, and the University of Missouri. He also spoke to students about careers in NOAA. He spoke with the producer of a Discovery Channel program on ice storms.
- Several CIMMS scientists provided input to a CBS disaster mini-series that aired in mid November.
- Phillip Spencer is an EARTHSTORM mentor for an elementary class in Enid, OK. Phillip Spencer teaches an Introduction to Meteorology course at OU and is an EARTHSTORM mentor for an elementary class in Enid, OK.
- Kevin Manross gave a tour of NSSL for 11 kids and 4 chaperones from the Pauline E. Mayer Children's Shelter.
- Melissa Bukovsky helped to guide about 30 Junior Girl Scouts through various requirements of a weather-related badge as part of an all day workshop aimed at sparking interest in various geosciences fields. Ric Adams gave five tours of NSSL facilities to various groups and officials.
- Don Burgess gave a lecture on radar and radar observations to a freshman Introduction to Meteorology class at OU. Don Burgess gave a presentation on the Fujita Scale for classifying tornado damage to a group of high school students visiting from Minnesota. He also served on the committee of an M.S. student at the University of Oklahoma.
- Sebastian Torres served as a judge for the regional State Future City Competition for middle school students sponsored by several state and national engineering organizations.
- Christopher Godfrey served as a judge at the Oklahoma City Community College Regional Science Fair.
- Susan Cobb conducted a Cub Scout group on a tour of displays and the weather trail at the National Center for Atmospheric Research in Boulder, CO. She also answered 40 letters sent to NSSL's website.
- Kevin Manross assisted with a tour of NSSL for a cattlemen's group. Phillip Spencer was a judge at the Mesonet Science Fair at the University of Oklahoma.
- Pam Heinselman led a four-week internship for a high school senior from Albuquerque Academy and gave a seminar for the REU students about how to review a scientific paper.

- Daphne Zaras conducted tours of NSSL for a total of 274 people (102 adults, 8 college students, and 164 kids) about lab activities and responded to 237 phone calls and 303 e-mail letters sent to the NSSL and CIMMS web sites. Group tours included the Norman Chamber of Commerce Weather Committee and a group of college students from the Texas A&M Meteorology Club. She was interviewed by the Oklahoma State Regents of Higher Education's radio show, Scholastic Math Magazine, and Scholastic World Magazine. She talked extensively one day with a New Jersey high school teacher about using weather data in a computer science programming class. Daphne worked with two high school students and an adult (returning to college to major in meteorology) who do volunteer work at NSSL. She talked with several dozen OU students about current and future opportunities at NSSL during the School of Meteorology Career Fair, spoke with several hundred middle school students at the Moore Norman Technology Center Career Fair about NSSL and careers in meteorology, and gave several tours of NSSL to student groups. She talked about severe weather threat and safety to several hundred Air Force personnel at Tinker Air Force Base and talked about storm chasing and answered questions about science and careers in meteorology at a workshop for K-12 teachers. She served on the local planning committee for the National Severe Weather Workshop held in Midwest City, OK. Daphne served as the faculty resource person for a course on the Oklahoma weather enterprise for the Oklahoma Scholar-Leadership Enrichment Program (OSLEP), a week-long intercollegiate academic program for Oklahoma college and university students.

NWS Norman Forecast Office personnel launch a weather balloon during the Open House portion of the NSSL 40th Anniversary celebration in fall 2004.

Outreach Activities of CIMMS Staff at WDTB

Decker, Morris, Schlatter, Wood (primary – CIMMS at WDTB)

Objectives

Inform college students, emergency personnel, and the general public about warning-related research and training issues.

Accomplishments

Outreach activities conducted during the fiscal year include:

- Submission of proposal to NOAA's office of education and sustainable development (OESD) that would organize an outreach program for emergency managers, broadcasters, and teachers
- Participated in OK-FIRST Certification workshop
- Assisted with planning National Severe Weather Workshop
- Participated in OCS workshop "Innovations in Weather-Impacted Disasters" co-hosted with emergency managers from 13 states
- Gave Presentation for the Lawton West Rotary Club
- Provided an outdoor classroom presentation with approximately 300 4th graders at Weatherford, OK Schools
- Gave two lectures to meteorology students at the University of Oklahoma and students at the University of Massachusetts, Colorado State University, and the University of Puerto Rico at Mayaguez via simulcast
- Gave one in-class lecture to a University of Oklahoma graduating meteorology Capstone class
- Mentored an REU student with a project titled "Hail Warning Decision Guidance"
- Attended Norman Chamber of Commerce, Weather Committee and sub-committee meetings
- Participated in a career fair panel discussion to assist students looking for employment in meteorology

Outreach Activities of CIMMS Staff at SRH – *Spanish Language Forecasts, Watches, Warnings, Advisories now Available on NWS Southern Region Web Sites*

Minton (CIMMS at SRH)

Objectives

Make Spanish language forecasts, watches, warnings, advisories, and hazardous weather outlooks available to the public.

Accomplishments

NOAA National Weather Service (NWS) Spanish language forecasts, watches, warnings, advisories and hazardous weather outlooks are now just a mouse click away on 32 NWS Southern Region Weather Forecast Office (WFO) web sites. Each WFO web site opens to a watch, warning, advisory map containing the phrase *Experimental: en español* in the upper right hand corner. Clicking the phrase links visitors instantly to weather information in Spanish.

"The Hispanic population in the United States represents one of the fastest growing segments of our society," said Bill Proenza, director, National Weather Service Southern Region. "This is particularly evident here in the Southern Region. This new service represents a major step forward in providing easier access to vital, life-saving weather information for millions of our citizens who may have been at greater risk due to the language barrier."

According to the latest U.S. Census Bureau data on persons over the age of five years, approximately 28 million people (nearly 11 percent) – come from homes where Spanish is spoken. In the 10 southern states, Puerto Rico and the U.S. Virgin Islands that make up the NWS Southern Region, nearly 13 million people (18 percent) come from Spanish speaking households.

In April, NWS Southern Region Headquarters (SRH) Information Technology Analyst Leon Minton, WFO El Paso Information Technology Officer Rod Heckel and Fort Worth Journeyman Forecaster Dennis Cain joined forces to meet an obvious need for this substantial segment of the Region's population. "In order to re-create the maps, zip code/city search engine, local observations and Point Forecast pages, we created 60 Spanish versions of corresponding English scripts," said Minton. "Dennis Cain then created 16 Spanish versions of the English forecast image banners."

This work allows the Forecast Offices to use a new Interactive Forecast Preparation System (IFPS) to draw raw weather data directly from the NWS National Digital Forecast Database (NDFD) to automatically create Spanish language Point Forecast pages.

If visitors click on the watch, warning, advisories or hazardous weather outlook links, they also experience a seamless transition to Spanish translations. As these products are received at the SRH web farm, they are forwarded to WFO El Paso where they are translated by computer, returned and easily accessed via local NWS web sites.

Minton added, "There were thousands of hits the first day the Spanish Language links were posted, and we have seen a steady increase since then." Leon Minton provides information technology expertise for the NWS Southern Region by virtue of a University of Oklahoma grant under the Cooperative Institute for Mesoscale Meteorological Studies (CIMMS) program.

Rod Heckel has been recognized with a 2005 NOAA Administrator's Award for his pioneering work in the development and implementation of automated Spanish language broadcasts via NOAA Weather Radio All Hazards (NWR). The Weather Forecast Office in El Paso was the first in the nation to have an NWR transmitter totally dedicated to Spanish language broadcasts.

Appendix A

CIMMS AWARDS AND HONORS

2005 Sergey Soloviev Medal – April 2005

Charles Doswell III – CIMMS Research Scientist

The Sergey Soloviev Medal has been established by the European Geosciences Union's Session on Natural Hazards in recognition of the scientific achievement of Sergey Soloviev. CIMMS scientist **Chuck Doswell** was the 2005 recipient of the Medal. His award announcement is as follows:

Charles A. Doswell III wins EGU Sergey Soloviev Medal 2005

The American meteorologist Charles A. Doswell III has won the prestigious EGU Sergey Soloviev Medal in recognition of his world leadership in predicting the consequences of severe storms and floods, and in the avoidance and mitigation of these severe natural hazards.

This medal has been established by the EGU Section on Natural Hazards in recognition of the scientific achievement of Sergey Soloviev. It is reserved for scientists for their exceptional contributions to natural hazards, in particular, for their research aiming at an improvement of our knowledge of basic principles as well as for the assessment and proper mitigation of hazards in view of environmental protection and the integrity of human life and socioeconomic systems.

Dr. Charles A. Doswell III has significantly contributed to understanding severe convective storms and their accompanying weather namely tornadoes and downbursts, significant hail and flash floods. Not only is he the leading and best recognized scientist in this research area but he has spent enormous energy in publicizing and drawing attention to these natural hazards among the general public and among governmental authorities.

Charles Doswell will accept his medal and give a lecture, titled **'Progress toward developing a practical societal response to severe convection'** at the EGU General Assembly, to be held in Vienna, Austria from 24 – 29 April. The lecture starts at 10.30 – 11.30, at the 26th of April.

Charles A. Doswell III is a senior research scientist at the Cooperative Institute for Mesoscale Meteorological Studies, Norman, Oklahoma United States.

Certificate of Appreciation from NWS Southern Region Headquarters – May 2005

Leon Minton – CIMMS Scientist at SRH

Information Technology Analyst **Leon Minton** has received special recognition for his outstanding service to the National Weather Service and Southern Region Headquarters. During the last five years, Minton has been providing information technology expertise for the NWS Southern Region by virtue of a University of Oklahoma grant under the Cooperative Institute for Mesoscale Meteorological Studies (CIMMS) program.

A certificate of appreciation, signed by Southern Region Director Bill Proenza, was presented to Minton in a brief ceremony at SRH. It reads, "In recognition of your outstanding and innovative programming support to the National Weather Service and Southern Region." Minton has been an integral part of many of the SRH's innovative programming efforts to support and enhance the Region's forecasting and warning capabilities.

One of the most recent innovations concerned the development of Spanish Language web pages to provide forecasts, watches, warnings, advisories and outlooks for the fastest growing segment of the U.S. population. Working in concert with NWS forecasters, he applied his programming skills to help create seamless Spanish translations.

This work allows the Forecast Offices to use a new Interactive Forecast Preparation System (IFPS) to draw raw weather data directly from the NWS National Digital Forecast Database (NDFD) to automatically create Spanish language Point Forecast pages. Hispanic visitors to NWS web sites in the Southern Region need only click on a link for instant Spanish language translations.

NWS Deputy Regional Director Steven Cooper (right) presents Certificate of Appreciation to IT Analyst Leon Minton.

NOAA OAR Outstanding Scientific Paper Award

Igor Ivic, Sebastian Torres, and Dusan Zrnic – CIMMS Scientists at NSSL

CIMMS scientists Igor Ivic and Sebastian Torres, along with CIMMS Fellow at NSSL Dusan Zrnic, won the NOAA OAR Outstanding Paper Award made during the fiscal year for their 2003 paper, “Whitening in range to improve weather radar spectral moment estimates. Part II: Experimental evaluation”. This paper was published in the AMS *Journal of Atmospheric and Oceanic Technology* (Vol. 20, p. 1449-1459).

American Meteorological Society Special Award – 85th Annual Meeting, 2005

The Oklahoma Mesonet

The Oklahoma Mesonet, a unit of the Oklahoma Climatological Survey, of which CIMMS Fellow Renee McPherson is acting director, received an AMS Special Award at the 85th AMS Annual Meeting "for serving Oklahoma and the meteorological community by providing high-quality data and information products used to protect lives, reduce costs, facilitate cutting-edge research, and educate the next generation"

Nominated by NWS for a Department of Commerce Gold Medal for their development of the Advanced Warning Operations Course (AWOC)

Warning Decision Training Branch

Yoshi Sasaki Award for Best M.S. Student Publication for 2005

Zewdu Segele – CIMMS Graduate Student

Appendix B

PUBLICATION SUMMARY

	CIMMS Lead Author				NOAA Lead Author				Other Lead Author			
	2001-02	2002-03	2003-04	2004-05	2001-02	2002-03	2003-04	2004-05	2001-02	2002-03	2003-04	2004-05
Peer Reviewed	27	32	42	40	7	20	10	15	18	30	24	31
Non-Peer Reviewed	37	52	56	81	7	17	9	24	11	21	8	27

2004-05 Summary			
Author	**Peer Reviewed**	**Non-Peer Reviewed**	**Total**
CIMMS Lead Author	40	81	121
NOAA Lead Author	15	24	39
Other Lead Author	31	27	58
Total	**86**	**132**	**218**
Theses	**6** (4 M.S. and 2 Ph.D.)		

(Publication numbers are approximate; those listed throughout this document as "Submitted", "In Review", or "To be Submitted" are not included in the above summary; however, those listed in the document as "Accepted" or "In Press" are included in the above summary)

Appendix C

PERSONNEL SUMMARY

NOAA Funded Research

Category	Number	B.S.	M.S.	Ph.D.
Research Scientist	42		24	18
Visiting Scientist	6	1	2	3
Postdoctoral Fellow	0			
Research Support Staff	22	8	10	
Administrative	4	3	1	
Undergraduate Students	20			
Graduate Students	9	5	4	
Total	**103**	**17**	**41**	**21**
Located at NOAA Unit	SPC-2; SRH-1; ROC-10; WDTB-9; NSSL-75			
Obtained NOAA employment within past year	1			

Non-NOAA funded Research

Category	Number	B.S.	M.S.	Ph.D.
Research Scientist	14		8	6
Visiting Scientist	0			
Postdoctoral Fellow	0			
Research Support Staff	1			1
Administrative	2		1	1
Undergraduate Students	12			
Graduate Students	15	9	6	
Total	**44**	**9**	**15**	**8**

Appendix D

EXECUTIVE SUMMARY OF CIMMS STRATEGIC PLAN

See next page

Cooperative Institute for Mesoscale Meteorological Studies

STRATEGIC PLAN

Vision

A center of research leadership and excellence in mesoscale meteorology, weather radar, regional climate, and forecast and warning improvement, fostering strong government/university collaborations

Mission

To promote collaborative research between NOAA and OU scientists on problems of mutual interest to improve basic understanding of mesoscale meteorological phenomena, weather radar, and regional climate to help produce better forecasts and warnings that save lives and property

CIMMS GOALS

Goal	CIMMS PROGRAM OUTCOMES
Mesoscale Meteorology *Perform fundamental research on mesoscale and convective weather processes*	Improved understanding of the structure and behavior of deep convection such as supercell storms, tornadoes, damaging straight-line winds, large hail, and heavy snow Improved understanding of the feedbacks between cloud microphysical, radiative transfer, and dynamical processes Improved understanding of mesoscale dynamics and storm scale data assimilation
Weather Radar Research and Applications *Perform research on weather surveillance radar and develop prototype economical applications and technologies for optimal operational deployment*	Improved quantitative precipitation estimation in the near real-time for watershed management and for better flash flood detection, warnings, and forecasts, including use of prototype dual polarization radar data Feasibility research and development to explore the capability of phased array radar for weather surveillance Expanded WSR-88D network capabilities to extend the network's useful life well into the first quarter of the century Improved radar input into severe thunderstorm and tornado warnings
Forecast and Warning Improvements *Transfer research findings into knowledge, technology, and training that can be used to improve forecasts and warnings*	New and innovative applications, methods and technologies that streamline forecast and warning decision processes and practices and assist forecasters in the detection, diagnosis, and prediction of severe weather Quick and successful science and technology transfer into NWS operations Forecasters trained in the latest warning decision making techniques New and innovative ways to disseminate and display weather information for the general public
Regional Climate and Climate Change *Perform research to improve understanding of the relationships between mesoscale processes and regional climate and develop techniques to monitor climate and detect its changes*	New insights into the complex land-atmosphere interactions over the agriculturally important U.S. Midwest Improved understanding of the influence of North Atlantic cyclones on the weather and climate of surrounding areas Improved understanding of the potential feedback between the atmosphere and the land/ocean/cryosphere New insights into the potential links between climate variability and severe storm frequency and severity Climate indices and indicators that provide early detection of important climate changes in the U.S.
Societal and Economic Impacts *Assess the impact to society and the economy of storm systems and regional climate variability and make that information available to policy makers and the public and private sectors*	Socioeconomic impact assessments of severe weather such as tornadoes and hurricanes Monthly and seasonal residential natural gas consumption indices east of the Rocky Mountains Improved forecasts of unusual climate anomaly occurrences to mitigate possible social and economic losses Energy usage and agricultural applications based on summertime temperature extremes analysis
Outreach and Education *Support outreach and education programs to educate, engage, advise and inform the public, teachers and students*	Public awareness of mesoscale meteorological phenomena and their potential impact on people's lives Enlightened college interns guided by mentors through unique summer research projects K-12 teachers in Oklahoma and Kansas equipped with valuable ideas and resources for teaching weather and climate concepts Diverse, outstanding graduate students
Administration and Development *Provide an optimal framework with which to manage the financial, technological, physical, and personnel resources needed to support a world-class research staff*	A highly-skilled, motivated, effective, and collaborative workforce